PRACTICAL PAPER-MAKING

A MANUAL
FOR PAPER-MAKERS AND OWNERS AND
MANAGERS OF PAPER MILLS

TO WHICH ARE APPENDED

USEFUL TABLES, CALCULATIONS, DATA, ETC.

BY

GEORGE CLAPPERTON

PAPER-MAKER

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PRACTICAL PAPER-MAKING.

CHAPTER I.

CHEMICAL AND PHYSICAL CHARACTERISTICS OF VARIOUS FIBRES.

As the chemical and physical characteristics of the materials from which the paper-maker draws his supply determine to a marked degree the quality of the finished product, a thorough grasp of these characteristics is indispensable to all who aim at the production of the best possible results with the minimum of cost.

The percentage of cellulose—or, to use a term more readily understood by paper-makers, the amount of available paper-making material—varies with the plants from which it is obtained, and the treatment to which it is subjected in the process of freeing it from its combination with the non-cellulose or non-available material with which it is so intimately bound up.

The chemical formula for cellulose is $C_6H_{10}O_5$, which means that 6 equivalents of carbon, 10 of hydrogen,

and 5 of oxygen are united together to form the substance known by that name. These proportions are constant, though the physical characteristics may differ very widely, and it is of the first importance that great care be taken, in the different processes through which the raw material must pass, that none of the chemicals employed have the effect of changing its nature by adding to or taking from its constituents, thus giving rise to serious complications.

Cellulose which has been in contact with bleaching solution for a lengthened period, or even exposed to the action of air and light for any length of time, will be found to have lost much of its original strength and firmness, and in addition to have acquired properties that were wanting in its pure state. This change is due to the action of the atmospheric oxygen in entering into combination with the cellulose molecule to form what is technically known as the oxy-cellulose obtained by the action of a weak oxidising agent on cellulose.

The oxy-cellulose has the property of extracting basic colouring matters from their solutions and being permanently dyed by them, and further possesses an extraordinary affinity for vanadium compounds, uniting with them from solutions containing infinitesimal proportions.

Pure cellulose is insoluble in all simple solvents. A solution of cupric hydrate in ammonia alone acts on it, first causing it to swell up, and finally dissolving it. The reaction with a solution of iodine in potassium

iodide is mostly used for its detection; but in order to render it effective it is necessary to employ a dehydrating agent, such as sulphuric acid, when the characteristic deep blue or violet colour will be produced.

Before the cellulose can be made available for the manufacture of paper, it must first be freed from its combination with the non-cellulose constituents with which it is united to form the plant structure.

Plants may be designated as an aggregation of fibres and cells bound together by gummy, resinous, and waxy substances, which have a function similar to that performed by lime in cementing and rendering durable the stones or bricks of which a house is built; and as the stones, in order to be used in the building of another house, would first have to be freed from the lime with which they were bound together in the previous structure, similarly the fibres and cells must be freed from all substances which, though indispensable to their existence in the plant life, would tend to impair their value as paper-making material.

Cotton differs from the other plants in this, that by the natural process of ripening the fibres are so freed as to yield a pure cellulose, which is available without the preliminary treatment which the compound celluloses must undergo. These compound celluloses are classed under the following heads:

(1) *Pecto-celluloses*, so named because they yield pectic acid on the breaking up of their combination.

The flax plant may be taken as typical of the celluloses comprising this group.

(2) *Ligno-celluloses*, which owe the designation to their yielding non-cellulose or lignine as the result of their disintegration. Jute is the typical cellulose of this group, in which are included all the different forms of woody tissue.

(3) The third group exist in such a small proportion in paper-making materials, that, as compared with the preceding compound celluloses, they are of little importance. They are known by the name *adipo-celluloses*, and are so termed because on reduction they yield acids analogous to those obtained by the reduction of fats and cork tissue. This group embraces the cuticular tissue of such plants as straw, esparto, and cotton.

The problem, then, which presents itself to the practical paper-maker for solution is not simply to become acquainted with the physical features of the fibres he desires to use for the production of his paper, but to arrive at the most economical method by which he can best secure the liberation of such fibres in the form most suited to his particular purpose, while preserving as far as possible the original strength.

Such materials as rags and thread, which have already been subjected to retting, boiling, and bleaching by the textile manufacturer, require no very drastic treatment to render them suitable to the needs of the paper-maker, as they are already in a more or less pure state before coming to his hands.

It is for this reason, coupled with the physical characteristics of their fibres, that they are so much valued by him. It will be readily understood that it is with such materials as esparto, straw, and wood that the chief difficulties in the way of extracting the available cellulose exist.

In addition to the fact that esparto and straw have been subjected to no previous disintegration, there is another reason which renders them less valuable as a paper-making material. In the process of the building up of their plant structure the fibro-vascular bundles, from which the available fibres are obtained, are scattered irregularly throughout the main mass, and are more closely connected with the non-cellulose constituents than are the "bast" fibres of flax, hemp, and jute, the fibre bundles or "filaments" of which form a separate and cohesive tissue, and are thus more easily freed from the surrounding non-available material.

Before taking up the different processes through which the materials are passed, in order to render them fit for the production of paper, a glance at the physical features of the various fibres will be of material assistance in enabling the paper-maker to obtain a knowledge of the conditions best suited to their successful treatment.

The ultimate fibres of the cotton plant consist, as before stated, of pure cellulose, and on examination under the microscope will appear as long, flattened,

tubes always more or less twisted upon themselves. The side walls are rough and granulated, which is most easily seen when dry. They are strong and flexible, and suited for the production of the finest qualities of paper, though from the spongy nature of the fibre the finished sheet is less hard than that made from linen. When the tubular form of the fibres is borne in mind, it will be at once understood why the colouring matter is so difficult to remove from coloured cotton rags. (See Plate I., *Frontispiece*, fig. 1.)

Linen, the fibre of the flax plant, is, like cotton, tubular, but the side walls are much thicker, the central canal is smaller, and, consequently, the fibre is harder and less spongy. (See Plate II., figs. 3 and 4.)

Papers made from linen rags are hard, strong, and firm to handle. The fibres obtained from ropes and bags are mostly hemp, and are somewhat like linen, but much more coarse and harsh; as they are seldom completely freed from the incrusting matters they require to be boiled with a larger percentage of caustic.

Jute fibres are strong but very difficult to bleach white, and, indeed, if subjected to such treatment as will dissolve all the extraneous matter, and reduce to ultimate fibres, their original strength is much impaired.

Manilla hemp yields strong fibres, easily detached, but, like jute, somewhat difficult to bleach white. (See Plate I., *Frontispiece*, fig. 2.)

The ultimate fibres of esparto are short, smooth, and tubular, but in some places the central canal is

Plate II.

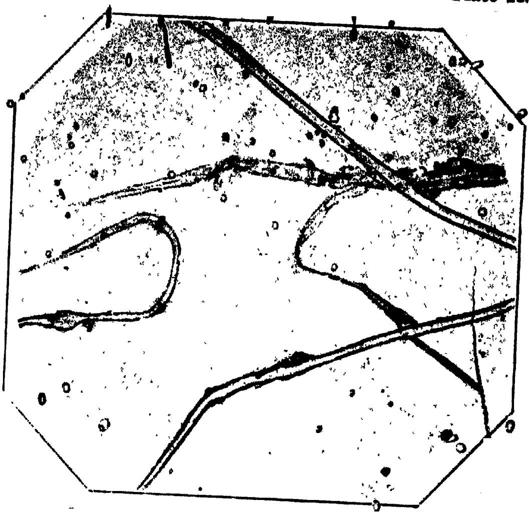

FIG. 3.—LINEN × 130.

FIG. 4.—FLAX × 130.

[To face page 6.

completely hidden by the thickening of the side walls. (See Plate IV., fig. 7.)

Straw fibres are very similar in appearance to esparto, but they are shorter and more highly polished, thus tending to make their felting power much less, and rendering paper made from them very brittle. (See Plate IV., fig. 8.)

Wood fibres vary with the different species from which they are obtained and the methods used to isolate them. Pine wood is capable of yielding long, soft, transparent, flexible fibres, well suited to the production of strong well-felted papers. Ash and similar trees yield short, hard fibres, possessed of no great felting properties. (See Plate III., fig. 5.)

CHAPTER II.

CUTTING AND BOILING OF RAGS.—JUTE BOILING AND BLEACHING.

Grading of Rags.—As the quality of the finished paper is dependent on the successful carrying out of the different processes through which the stock must pass, it is indispensable to the production of a uniform and satisfactory result that the greatest care be taken in each department to ensure the intelligent application of the principles on which each process depends.

Nowhere would a neglect of the requirement of each particular class be more disastrous than in the rag room, which may not inaptly be termed the birthplace of the varied qualities of beautiful papers which are met with in the market.

Carelessness in the regulations of the standard of each particular grade of rags cannot fail to lead to mischievous results, as in such circumstances the stock may at one time be above the usual quality intended for the paper made, and, at another, much inferior; and yet with such manifest defects the paper produced

is expected "to be equal to last, making in every respect."

The only remedy for such a state of matters, which is not an uncommon one, is that the official in charge of the department should insist that the cutters and sorters give the necessary attention to the strength and cleanliness recognised as the standard of each grade. If this be done consistently and intelligently, it will soon make itself known in the smoothness with which the subsequent processes will go forward, and in uniformity in the purity, strength, and shade of the paper made which will far more than repay the extra time and care involved.

Rag-cutting.—Though the rag-cutting machine has been much improved of late years, it cannot be said to have superseded cutting by hand, especially for the better qualities of paper.

As will be readily understood, the rags in being cut by the machine come far less under the supervision of the women whose duty it is to grade the different qualities used in the mill; and this, together with the fact that in the tearing and cutting on the machine much of the best of the fibres is damaged, presents a serious drawback to its adoption.

In cutting strong, coarse material, such as canvas and bagging, these defects do not exist to the same extent, and, though they did, would be of less importance; consequently it is more suited to that class of stock.

When the rags are run straight from the cutter into the dusting-machine, as is often the case, the carrying felt should be long enough to admit of standing room for sorters on either side, so that any extraneous material, such as wool, silk, etc., which may have escaped detection when feeding in the rags, may be removed, and thus prevented from finding its way into the boilers and, it may be, into the finished paper.

Rag Boiling.—The object in subjecting rags, or other paper-making material, to the process of boiling is that the reducing action of the water, aided by the temperature and pressure employed, may break up the combination of the cellulose with non-available substances.

Caustic soda is the chemical usually employed to render this action more thorough, and to ensure the complete removal of all the incrusting substances which by their presence tend to render the subsequent bleaching process much less effective, and to otherwise impair the value of the material.

Rags, which have already been subjected to such a process before coming into the hands of the paper-maker, require to be treated with a much smaller amount of caustic compared with such raw materials as esparto and straw. In the case of rags, the function of the soda is to remove the size, which is often applied to the fabric, together with any dirt which may have become attached to the interstices of the material

in its journey from the textile factory to the rag store, and also to destroy, as far as possible, any colouring matter and render it more susceptible to the action of the bleaching solution. Caustic soda has, in addition, the effect of softening the fibres, thus rendering them more flexible.

As the feel and look of a paper depend quite as much on the elasticity and complete freedom from all incrusting matters of the original fibres, as upon the treatment they receive in the subsequent operations of breaking and beating, it becomes at once apparent that what at first sight seems a very simple matter—namely, the determination of the amount of caustic soda most suitable for each material—is in reality a somewhat difficult problem, and one which requires much greater consideration than is usually given to it.

The physical nature and condition of some rags may be such as to render them quite inert, and of little felting power, should they be boiled with the amount of caustic necessary to the production of a good colour when bleached. The wisdom of continuing to use such materials, even though obtained at a comparatively low price, is, to say the least, very questionable.

Some rags, again, which from the standard of cleanliness may not require a large proportion of soda, will often be found to be greatly improved by using a little extra per hundredweight, especially when the

fibres are harsh. The softening which is thus obtained will make itself apparent in producing a closer and more evenly felted sheet.

With regard to the economy of using low quality rags for papers in which a good colour is indispensable, it has been shown, as the result of very exhaustive experiments carried out by Messrs. Wurster and Zugler, that bleached half-stuff from cheap rags is in the end much more costly than that obtained from the better qualities, notwithstanding the great difference in the price. As much as 18 per cent. of loss was found in the boiling and washing of such materials.

Some paper-makers prefer to boil their stock with lime, in place of caustic soda, and this is especially the case in America. For the better qualities of paper, however, its use is attended with very serious drawbacks. A larger proportion of lime than is actually necessary to reduce the stock must always be used, and as this excess must be properly washed out of the rags before bleaching, both time and water are thus consumed.

Gritty matters, such as sand and coal-dust, are invariably present, even in the best qualities of lime, and these are apt to become fixed in the fibres in such a way as to render their complete removal a matter of some difficulty.

Lime, as is well known, is but sparingly soluble in cold water, and still less so when the water is heated. One part of lime requires seven hundred parts of cold

water to dissolve it, and fifteen hundred parts when the temperature is raised to boiling point.

During the boiling process, however, a much larger quantity is dissolved than would appear possible at first sight. As the dissolved lime enters into combination with the non-cellulose portion of the stock, the water becomes capable of dissolving a further quantity, and so the dissolving action is repeated until all the fatty and resinous matters have entered into combination with the lime.

In preparing coarse, dirty stock, such as jute and the lower grades of flax, in the subsequent application of which a high degree of cleanliness is not of the first importance, lime may be used with advantage, both on account of its cheapness and its reducing qualities.

In selecting a lime to boil with, it should be borne in mind that grades showing the same percentage of actual lime do not always produce a uniform result in treating the stock. Lime which is light to handle, of a uniformly white colour, and which slacks easily, seems to possess greater reducing power than a dull-coloured, heavy lime, as less of it is required for boiling, and the pulp produced has a softer feel.

Caustic lime when exposed to the atmosphere quickly absorbs carbonic acid, and the carbonate of lime thus formed, in addition to possessing no boiling power, is very liable to cause serious complications in the subsequent operations by adhering to the fibres even after much washing, and is frequently the source of the spots

which at times appear so unaccountably on the machine wire.

Stationary boilers are very suitable for the finer grades of cotton and linen rags, but for coarse, dirty stock the rotary action of the revolving boiler is of advantage, as the shaking thus given to the stock has the effect of loosening the dirt. For this reason it is usually employed for such materials. It is an additional advantage if the boiler can be fitted with a system of pulleys, which will enable the revolving action to be quickened during the washing which follows the running off of the spent liquor.

Jute Boiling and Bleaching.—Jute is a material which, on account of its strength and cheapness, would receive much more extensive application in the manufacture of paper were it not for the almost insurmountable difficulties which lie in the way of producing from it, at a reasonable cost, a pulp of sufficient whiteness to be used in the making of fine papers.

The chief difficulty in bleaching lies in the fact that, unless the boiling process has been conducted so as to ensure that all the incrusting matters have been dissolved, the amount of chlorine consumed before these incrusting substances can be effectively bleached more than counterbalances the low price of the raw material. Apart from the cost of bleaching, the use of such a large amount of chlorine tends to impair the strength of the fibres.

The methods of boiling and bleaching jute vary with the particular requirements for the papers to be produced; but in mills using a considerable quantity, lime is, on account of its cheapness, generally employed to effect the separation of the non-cellulose substances.

Very good results are said to be obtained by boiling the jute with lime, under pressure, and then allowing it to stand, loosely stacked, in contact with the excess of lime that has been used in boiling.

After standing for some time the jute is washed and again boiled, this time with soda-ash under atmospheric pressure. The bleaching is conducted in the usual way by means of the bleaching powder solution; but instead of running in the amount necessary at one time, it is run in in small quantities, and before each supply is added the contents of the engine are tested by potassium iodide and starch papers, to ensure that all the chlorine has acted on the incrusting substances. In this way the fibres are said to be better preserved in their original strength.

In continental mills, where the old method of gas bleaching is still in vogue, jute is sometimes subjected to a preliminary bleaching by means of chlorine gas, before being bleached by the bleaching powder solution. The following method is said to produce a very satisfactory pulp.

The jute is boiled with a solution of milk of lime, at a pressure of about twenty-two pounds per square inch, for ten to twelve hours, the weight of lime used being

about 15 per cent., calculated on the raw material. After draining and washing the boiled jute is passed through a centrifugal machine and so freed from moisture as to be readily acted on by the chlorine gas, which is the next feature of the process.

The chlorine gas is prepared in the usual way from hydrochloric acid and black oxide of manganese, and great care is taken that none of the hydrochloric acid finds its way into the bleaching chamber, otherwise the pulp would be rendered less strong. The jute is stacked in such a way as to be readily permeated by the gaseous chlorine, and is allowed to remain under its influence until the colour of a sample drawn out shows that it is about three-quarters bleached.

After lifting, the partially bleached jute is washed in the potcher with water containing a 1 per cent. solution of ammonia soda, which serves to dissolve the yellow chlorine compound that has been formed by the action of the gas on the incrusting substances. This washing completed, the stock is bleached in the usual manner with from 6 to 8 per cent. of bleaching powder solution. The amount of time and handling necessary for such a method as that described would lead to the supposition that it is very doubtful if, in the end, such methods pay.

CHAPTER III.

WET PICKING.—WASHING, BREAKING, AND BLEACHING.—ELECTROLYTIC BLEACHING —ANTICHLOR.

Wet Picking.—It is the practice in most mills to subject the boiled rags to another overhauling, or "wet picking," as it is usually termed. The idea of this is to insure the removal of any buttons, pieces of india-rubber, or other unsuitable materials which may have been overlooked in the rag-house, or have become apparent through the action of the soda, before the treatment in the washing engine renders their detection and removal so difficult as to be almost impossible.

Washing, Breaking, and Bleaching.—These three operations are usually conducted in the same engine. The washing is generally accomplished by means of a drum washer, which is perhaps the most effective and time-saving method that has as yet been adopted for rags. The clear water should be run in so that it may mix with the rags before they come under the

roll, and the drum should be placed so that it may rest on the rags just as they have rounded the end of the midfeather on the return journey. This is not so near the roll as to run the risk of lifting the finest fibres brought to the surface by the agitation, nor yet so far from it as to allow the dirt to settle down on the rags again.

The way in which the washing is conducted determines, within certain limits, the percentage of loss caused by the finest fibres passing away with the washing water through the meshes of the wire covering of the drum. Until the dirt has been freed from the interstices of the rags the roll should simply brush them, and thus by opening them up assist the water in carrying the dirt away. If the roll be put down to a hard grip before the dirt has been loosened it is almost impossible to wash them clean; and further, it has the effect of making the stuff short and free, or fast, as some prefer to call it, thus in a large degree impairing the strength.

There are two conditions indispensable to the production of strong, flexible, clean half-stuff—namely, dull tackle and plenty of time. To obtain a rag at its full strength, the breaking must not be carried further than is necessary to break up the fabric. When that is accomplished the roll should simply brush out the half-stuff, so that it may be strengthened by the milling, and yet kept as long as possible consistent with being "out of the rag." This can only be ob-

tained by having blunt plates and rolls. The bars in the plate are usually tapered away to one-eighth of an inch.

If the roll or the plate be too sharp, or too quickly brought together, the fibres, instead of being drawn out, will be cut, and rendered so free that they will not soften, even when allowed to mill for five or six hours. Thread and strong rags cut with the rag-cutting machine are very liable to gather into lumps before the roll, and to enable them to travel they have to be gripped more firmly at first than would otherwise be the case. When they have begun to travel the roll should be raised to a pitch which will not reduce them too much.

When the colour of the water leaving the drum shows that the dirt or colouring matter is well washed out, a good plan is to allow the drainings from the bleaching-house tanks to run on the rags for some time, still keeping the drum in action. When not used for this purpose the drainings may, with advantage, be used to dissolve fresh quantities of bleaching powder. When the dirt or colouring matter has been completely washed out, the drum should be raised and the bleaching solution run in. If it should happen that the bleach is added before the washing is completed, the dirt will become fixed on the fibres in such a way that no subsequent washing will serve to take it out.

Bleaching powder, or chloride of lime, is made by

saturating slaked lime with chlorine gas. When the compound thus obtained is dissolved in water, bleaching liquor, consisting of chloride and hypochlorite of lime, is formed, while the calcium hydrate is left as the lime mud. Chlorine gas in the dry state possesses no bleaching properties, but in the presence of moisture it decomposes the water, taking up the hydrogen to form hydrochloric acid and liberating the oxygen.

The oxygen thus set free has powerful oxidising properties, which are rendered the more active from its being in what is technically known as the nascent state. It attacks the vegetable colouring matters, and by destroying them imparts the white shade characteristic of bleached stock.

The old method of gas bleaching depends on this direct action of the chlorine gas when brought into contact with the wet half-stuff. Unless under exceptional circumstances, bleaching powder has quite superseded the gas-bleaching method.

This is due to the facility with which it can be applied, as well as to the increased yield of pulp; a much larger proportion being attacked and destroyed by the chlorine gas than is the case when the less drastic action of the hypochlorous acid of the bleaching solution is employed.

When the materials to be bleached are more than usually dirty or high-coloured, heat is often used to assist the action of the bleach in producing a good colour. Great care must be taken to see that the

temperature does not exceed 90° Fah., otherwise the stuff will be shortened, and the colour obtained will go back, especially if allowed to lie for any length of time before using.

Another method of obtaining a good colour is to add to the stock, while in contact with the bleaching solution, an agent which will, by decomposing the bleach, render it more effective. Sulphuric acid is often employed to do this, and, within certain limits, it has the desired effect. Its use is, however, attended with the serious drawback that if it be added in excess chlorine will be liberated. This chlorine attacks the fibres and weakens them. When only a small quantity of sulphuric acid acts on the bleaching solution, hypochlorous acid is liberated.

Hypochlorous acid is decomposed and yields its oxygen very easily, and in so doing is reduced to hydrochloric acid, which acts less injuriously on the fibres than chlorine.

Sulphate of alumina may be used with better results in preserving the strength of the fibres, probably due to the fact that the action being less violent there is less tendency to liberate the chlorine.

Professor Lunge uses acetic acid to gain the same end, and he claims that there is no impairing of the strength of the fibres as is the case when chlorine is liberated, or even when the hydrochloric acid, which is formed from the decomposed hypochlorous acid, remains in contact with the stock. On adding acetic

acid to the engine, the bleaching solution is decomposed, with the formation of hypochlorous acid and acetate of lime.

The hypochlorous acid gives off its oxygen, becoming reduced to hydrochloric acid, which in the presence of the acetate of lime immediately acts on it, regenerating acetic acid and calcium chloride. It will thus be seen that only a very small quantity of acetic acid need be used, owing to its continuous regeneration.

Another feature of importance is that the hydrochloric acid does not remain long enough among the stock in the free state to do the fibres any injury. In the case of rags, which have been imperfectly washed and thus retain a large proportion of alkali, it is recommended that a less expensive acid, such as sulphuric, be used to neutralise the alkali before adding the acetic acid.

In bleaching rags containing even a small proportion of jute, no auxiliary agent which has the effect of liberating chlorine should be used. If jute be treated with chlorine a characteristic yellow compound will be formed, and it is the formation of this yellow body which is the cause of the fading in the colour of jute containing stock when such agents as sulphuric acid or sulphate of alumina are used to assist in bringing up the colour.

Dr. Lunge claims that acetic acid may be added to the engine before the bleach is run in; but with the other agents the best results are obtained by adding

them to the pulp after the bleaching solution has become somewhat exhausted.

When using steam it is better to allow the bleach to become thoroughly mixed before heating it. The amount of bleach required to give a good colour varies with the quantity of dirt or colouring matter to be destroyed, and the treatment which the material has received in the boiler. Imperfectly boiled stock always consumes a much larger proportion before coming to a good colour.

Clean cotton and linen rags will require from 1 – 2 per cent., calculated on the dry bleaching powder, while the coarser grades will require 5 to 6 per cent. The addition of a little alumina or sulphuric acid to the better grades of cotton and linen rags has the effect of killing the black threads often present.

It is very important that the bleaching solution be maintained at a uniform strength, otherwise the colour will not be regular in shade. A solution which stands 6° Twaddle contains about half a pound of bleaching powder to each gallon. Bleaching powder seldom contains more than about 35 per cent. available chlorine, which is equivalent to saying that only 35 per cent. of the weight of the powder dissolved has the power of bleaching the stock.

Owing to the amount of calcium chlorate present in some bleaching powders, the available chlorine does not exceed 25 to 28 per cent. Calcium chlorate possesses no bleaching power, and even in the best grades

of bleaching powder the lime mud often retains a considerable amount of chlorine. In storing the powder prior to dissolving, it should be kept as cool as possible, as it is very liable to be decomposed with the formation of unavailable calcium chlorate if the surrounding atmosphere is heated.

The most suitable vessel in which to conduct the extraction of the chlorine is a circular iron tank fitted with a mechanical agitator, so as to insure that all the powder may come into contact with the water. As chlorine is so liable to be decomposed by the action of light, the vessels should be fitted with a covering so as to exclude it as much as possible. A convenient size of mixer is one which will contain about 7 cwts. of bleaching powder and 900 gallons of water.

The agitation should be kept up for at least two hours, and the time allowed for settling should not be less than seven or eight hours, as a muddy solution is much less active than one which is clear, besides leaving a deposit of lime on the fibres, which is liable to cause unevenness in the subsequent sizing operation, and to cause the spots which, at times, are such a nuisance in the machine wire.

After the first liquor has been run off, the tank should be filled up again with water or weak liquor drained from the bleaching house tanks, and the agitation and settling conducted as with the first extraction. A third liquor may be taken off and used

either for bleaching or for extracting a fresh supply of bleaching powder. A sufficient number of mixers should be used as to admit of running off a first and a second liquor together, and a third also, if it is to be used for bleaching, otherwise the strength of the solution as used at the potcher will not be uniform.

By draining the lime mud and using the liquor thus extracted, either to dissolve fresh powder or to mix with the bleaching solution, if it be sufficiently clean and of uniform strength, a very considerable amount of bleaching powder may be saved, especially in mills where the consumption is a large one.

Electrolytic Bleaching.—Within the last few years a great many experiments have been tried, with a view to superseding the expensive bleaching powder, by making use of the electric current to set free the oxygen contained in water, and thus make it available for bleaching purposes. It is well known that the oxygen generated from water by electrolysis has the power of decomposing colouring matters. The chief difficulty in the way of using the oxygen thus liberated lies in the fact that, though the incrusting matters are certainly removed from the fibres, they are liable to assume a brown colour on entering into combination with the oxygen. This brown colour can only be removed by using chlorine to decompose and bleach it.

Another method of bleaching without the use of chlorine, which, however, is still in the experimental

stage, consists in treating the stock with ozone, or, as it may be termed, "active oxygen." When an electric spark is passed through a jar containing air, it is found that the oxygen present has acquired much stronger oxidising properties. The oxygen which has undergone this change has been named ozone, and possesses much more effective bleaching power than ordinary oxygen.

In bleaching with this agent the oxygen, which has been in contact with the electric sparks, and thus contains a larger proportion of ozone, is led by a pipe to the bottom of the vat in which the stock to be bleached is placed. In its upward passage through the stock this ozonised oxygen is said to destroy the colouring matters so effectively that its advocates claim it to be 70 per cent. cheaper than the use of bleaching powder.

In another class of processes the electric current is made use of to render cheap chlorine compounds, such as chloride of magnesia, available for bleaching purposes by liberating the chlorine contained in them. The process which has, by reason of its practical application, claimed most attention from paper-makers is that of M. Hermite. The bleaching solution used in this method is obtained by decomposing a 5 per cent. solution of magnesium chloride by means of an electric current.

As the decomposition proceeds, magnesium and hydrogen are given off at the negative pole, while the

chlorine and oxygen go to the positive. The chlorine takes up the oxygen to form hypochloric acid, which is in turn decomposed with the formation of chlorous and chloric acids. As these acids yield their oxygen to bleach the stock, magnesium chloride is again formed and again decomposed as before, thus making the process continuous.

The loss in chemicals is made up by the addition of fresh quantities of the magnesium chloride. The bleaching solution prepared in this way is said to possess greater bleaching properties than a solution of bleaching powder containing the same percentage of available chlorine.

It is the practice in some mills to run the bleached stock into large chests fitted with perforated bottoms, through which the weak liquor is allowed to drain. In mills where a large stock is kept the rags may lie in the bleaching-house for weeks, and while it is quite true that the colour will come up, owing to the action of the sunlight in decomposing the chlorine compounds remaining in the stock, yet, if the exposure be too long, the colour will go back, and in addition the rags will become tender, owing to the formation of the oxy-cellulose by the action of the oxygen of the air in the presence of light.

This tendering and fading will be more apparent if auxiliary agents, such as sulphuric acid or sulphate of alumina, have been used in bleaching; and stock which has lain for a considerable time, especially if

sulphuric acid has been used, will often be found to have taken on a pinky tinge.

These drawbacks to the use of a bleaching-house have led some paper-makers to discard it altogether, and to run the rags straight from the breaking engine, in which the bleaching has been conducted, to the beater.

When this is done more bleach is required to give the same degree of whiteness, and owing to the presence of an increased amount of bleach in the undrained rags, a larger quantity of antichlor is rendered necessary to neutralise the chlorine than is the case when they have been allowed to drain in the bleaching house tanks. The ordinary grades of cotton and linen rags will be found to be at their best, both as regards whiteness and strength, after having lain for twenty-four hours in the bleaching house.

Antichlor.—Whether the stock has lain in the bleaching-house or has come direct from the washer, it retains chlorine to such an extent that the latter must be neutralised; otherwise its presence will act injuriously on the fibres, besides seriously complicating the reactions on which the sizing process depends for its efficacy.

The two forms of neutralising agents, or "antichlors," as they are termed, most commonly used are hyposulphite of soda and sulphite of soda. When hyposulphite of soda is employed, the reaction which

takes place may be represented by the following equation :—

$$2\,Ca\,Cl_2\,O_2 + Na_2\,S_2\,O_3 + H_2\,O = 2\,Ca\,SO_4 + 2\,H\,Cl + 2\,Na\,Cl.$$

which shows that the bleaching solution remaining in the pulp is decomposed with the formation of calcium sulphate, sodium chloride, and hydrochloric acid.

The formation of the last-named constitutes a drawback to the use of this agent, as, apart from its injurious action on the pulp, the acid tends to eat into the machine wire and so shorten its life. This latter action, however, is not so injurious as is commonly supposed, as the writer knows a machine the wires on which, though carrying nothing but rag stuff treated with the hyposulphite, run for thirteen and even fourteen weeks.

When using it great care must be taken to avoid an excess, as, though not generally suspected, the reason why so many photographs become stained and spotted, even when not exposed to the action of light and air, is that an excess of hyposulphite of soda has been used in the engine, the presence of which in the cardboard used for mounting has caused the discoloration.

A glance at the following equation will show that when sulphite of sodium is used none of the resulting compounds will have any injurious effect either on the paper or the wire :—

$$Ca\,O\,Cl_2\,O + 2\,Na_2\,SO_3 = Ca\,SO_4 + Na_2\,SO_4 + 2\,Na\,Cl.$$

Should an excess of sulphite of soda be used in the

making of photograph mounts, it is asserted that no bad results will ensue, and the same applies to all colouring or toning. These reasons have led many paper-makers to adopt it in preference to the hyposulphite. It should be borne in mind, however, that it takes about four parts of the sulphite to do the work done by one part of the hyposulphite.

When using rags the best plan to ensure the complete neutralisation of the chlorine, without using an excess of antichlor, is to supply the beater-man with a bottle of potassium iodide and starch solution, with instructions to put in one-half of the usual amount of antichlor while running in the water, and after the rags are furnished, gradually to add the remaining half until the blue stain produced on the addition of a drop of the testing solution to the pulp has grown faint and finally disappeared. To make this test satisfactory it should be performed before the addition of the alum, otherwise it is not so much to be depended upon.

No doubt all this attention means extra work for the beater-man, but there are few beater-men who, if the foreman will but spare the time to explain what the neglect of the precautions may lead to, will not gladly give the attention necessary. Such care will not only ensure satisfaction to the purchaser, but will also save the beater-man a considerable amount of trouble, in giving a more uniform shade, and guarding against the unaccountable rises and falls in colour which are of so frequent occurrence in some mills.

Plate III.

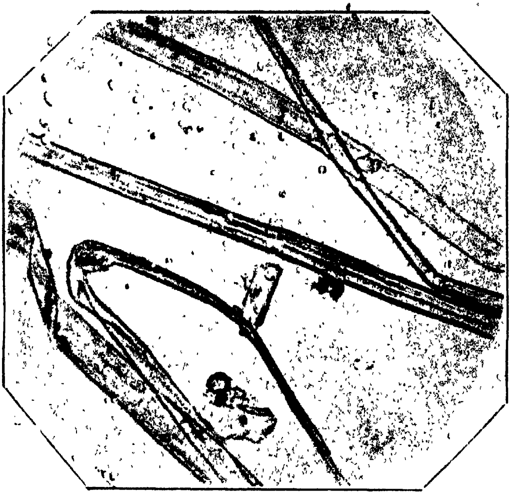

FIG. 5.—CHEMICAL WOOD × 130.

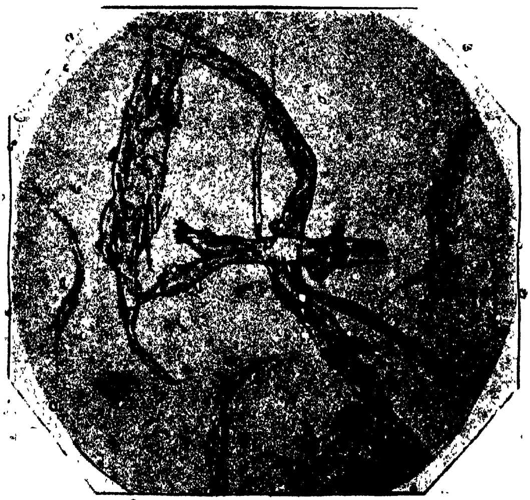

FIG. 6.—MECHANICAL WOOD × 130.

[*To face page* 32.

CHAPTER IV.

CELLULOSE FROM WOOD.—MECHANICAL WOOD PULP.

Cellulose from Wood.—Comparatively few paper-makers in this country prepare their own wood pulp, most of the supply being obtained from the Swedish and Norwegian pulp mills. A knowledge of the principles on which the different processes for obtaining the cellulose are based, and the effect of the treatment on the pulp produced, is, however, indispensable to the paper-maker, that he may be able to determine which pulp is most suited to his particular requirements.

Wood, like jute, belongs to the class of ligno-celluloses, and is composed of about two parts of cellulose, intimately bound up with one part of non-cellulose or lignin. The processes employed to break up this combination may be classed under three heads. First, the alkali process, which takes in the methods depending on the use of caustic soda. Second, the acid process, under which may be arranged the various

methods based on the reducing action of sulphurous acid in the gaseous or liquid state.

Midway between these two classes stand those of Dahl, Blitz, and Cross, the former of which employs a solution of sodium compounds containing a large percentage of sulphate of soda, and is known as the sulphate process. The process patented by Cross, mainly with the idea of rendering the use of lead-lined boilers unnecessary, while depending on the action of neutral solutions of the bisulphites provides for the use of alkalies. The boiling in Blitz's process is conducted by a solution of sodium sulphide, to which is added a very small proportion of vanadate of ammonia.

Whatever may be the process employed to produce the cellulose, the wood must first undergo a preliminary mechanical treatment in order that the pulp may be of a uniform character. The trees are first sawn into small logs, which are then stripped of the bark and cut into boards by passing through a slitting machine. The knots are next bored or cut out, and the boards broken into small chips by a breaking machine. The chips are then passed under heavy rollers, which bruise them in such a way as to allow the boiling solution to thoroughly soak them, and finally passed along revolving screens through which the dirt and dust, set free by the crushing, escape, while the clean chips are carried on to the boiler or store house as they may be wanted.

The caustic soda process of Watt and Burgess may be taken as the typical alkali method of isolating the wood cellulose. In this process the wood, having been subjected to such a treatment as that described, is digested in a large boiler with a strong solution of caustic soda, under a pressure of about ninety pounds, for ten or twelve hours. It is the necessity for employing such high temperatures and pressures that constitutes the serious drawback to the alkali processes, as under the conditions of boiling the strong caustic solution acts on the cellulose, impairing the strength and reducing the yield. The reason why such conditions are necessary is, that the soluble acid bodies resolved by the caustic become so oxidised and condensed that they counteract and weaken the reducing action of the soda, and in order to equalise their resistance higher temperatures and pressures have to be employed.

It is with a view to prevent the oxidisation of these acid bodies that the soluble bisulphide of sodium is used by Dahl. Notwithstanding the presence of this reducing agent, the pressure employed is high. It is in doing away with these counter-influences that the chief advantages of the acid processes lie. By using a solution of a bisulphite, such as lime or magnesia, the acid bodies are removed by entering into combination with the base, at the same time setting free the sulphurous acid, which acts on the unresolved wood until all the non-cellulose substances have been removed.

In Ekman's process the wood is digested in a large lead-lined, jacketed boiler, fitted so as to revolve when desired. The solution used is prepared by passing sulphurous acid gas, produced from burning sulphur in a stream of air, up through a tower, in which the magnesia, with which it combines to form the bisulphite, is loosely spread out. A stream of water, running down through the tower, meets the sulphurous fumes in their upward course, and carries them into solution.

Care is taken that the sulphurous acid and magnesia are kept at the proportions necessary to produce a double sulphite. The strength of the bisulphite solution thus obtained is about one-and-a-half per cent. of magnesia and four-and-a-half per cent. of sulphurous acid. When the steam is turned on, the pressure in the inner chamber increases with greater rapidity than in the outer, owing to the tension of the sulphurous vapour; but it is said that the best results are obtained by keeping the difference between the two pressures under thirty pounds.

As the pressure increases, the blow-off cock is opened that the gases may escape, and thus avoid over-heating and consequent discolouring of the wood. In about seven or eight hours the pressure reaches eighty-five to ninety pounds, and after about three hours' boiling at that pressure the action is stopped, and the wood, after washing and draining, is ready to be bleached.

In the Partington process the sulphurous gas is led into tanks containing milk of lime, and a bisulphite of lime solution at once obtained. By this method the boiling can be completed in from sixteen to eighteen hours, though in some cases, when increased pressure is employed, the time required is a little less.

While the principle underlying the various sulphite processes is the same in each case, they are divided into two classes, owing to the duration, or rather the differences which exist in the duration, of boiling. In what are termed the "quick" processes, the boiling is completed in from twelve to sixteen hours. To accomplish the complete separation of the cellulose and the non-cellulose substances in that time, a strong acid solution, at a high temperature, must be employed.

In the Mitscherlich process the solution used is much weaker, and contains a greater proportion of base. The result is that the boiling must be extended from forty to sixty hours, and the pressure is also much lower. By this latter treatment it is claimed that a larger percentage yield is obtained than by the quick methods of boiling. It is, however, difficult to see where this increase can come from, unless the incrusting substances are imperfectly removed, and so add to the weight of pulp produced. If this is the case it will soon make itself known by the increased amount of bleach necessary to give a good colour.

Wood and jute show a close analogy in chemical composition, and the difficulty experienced in bleaching

wood, from which all the incrusting matter has not been removed by the boiling, is due to the formation of a yellow chlorine compound similar to that produced when chlorine acts on jute. This yellow body must first be bleached before the cellulose is brought to a good white colour, and the amount of chlorine necessary to do this acts very injuriously on the fibres.

This weakening is also noticeable in highly bleached sulphite pulps; and though the degree of whiteness obtained, by using a large amount of bleach, makes such pulps suitable for the better qualities of paper, it is obtained at the sacrifice of much of the original strength and elasticity of the fibres.

Though Dahl's process is generally known by the term "sulphate," the solution employed to digest the wood contains other sodium compounds. It is principally composed of sodium sulphate, sodium sulphide, and sodium hydrate, and the strength of the recovered solution is maintained by the addition of fresh quantities of sodium sulphate. This process is said to possess a slight advantage over the caustic alkali methods in point of economy; but it is the general opinion among paper-makers that the pulp produced is inferior in strength, and less free from incrusting substances, than that obtained from the sulphite processes. Owing to the presence of these incrusting matters sulphate wood is, however, more suitable for the making of papers which are wanted opaque.

During recent years the demand for "sulphate"

pulp has increased largely, owing to the development of "Kraft" brown papers, which have entirely superseded certain classes of browns formerly used for wrapping purposes. The remarkable development of the Kraft brown branch of the trade is due to the fact that the Scandinavian makers were quick to realise the possibilities of pulp specially cooked to give the required characteristics.

In order to produce a pulp suitable for the Kraft papers, the boiling is conducted so as to ensure that encrustating matters are not fully resolved, with the result that the fibres are not injured, and retain their original strength in a marked degree.

It is a matter of much discussion among British paper-makers as to whether the characteristics obtained in the finished sheet are the result of the methods of boiling or the manner of beating, but it is probable that they are due to a judicious combination; and the fact remains that, notwithstanding painstaking experiments on the part of British makers, no Kraft yet produced in this country combines the crispness and elasticity which form so distinctive a feature of the Kraft papers produced by the best Scandinavian mills.

Another theory held to account for the superiority of the Scandinavian product is that the change in physical properties resulting from the action of the hot cylinders of the pulp machines, when the pulp is dried previous to being shipped, constitutes a serious

drawback to the production of strong, tough paper. With a view to overcoming this defect some British makers have shipped sulphate pulp containing 50 per cent. moisture; but notwithstanding that this pulp was specially prepared with a view to produce Kraft papers, the results cannot be said to have justified the increased cost incurred. It would seem that, owing to the presence of the by-products in the boiled pulp, the time allowed to elapse between the finish of the cooking and the beating or milling operation must determine to a large extent the properties of the finished product. Apart from such considerations as to boiling, the ability of the Scandinavian makers to allow a considerable time for milling the pulp in kollergangs or beaters must always remain a very considerable asset in their favour for the production of a crisp, tough Kraft paper.

A careful examination of the samples of the best Kraft papers will show that the individual fibres of the Scandinavian papers are much longer than those in the papers produced by British makers, and it is very probable that, even if the home maker could treat his pulp so as to retain the length of the fibres in the like degree, the product would be lacking in firmness and "rattle."

It would thus seem that the well-known characteristics of the Scandinavian papers are the result of the exceptional conditions under which they are prepared; and having regard to the practically unlimited supply

of power at the command of the manufacturers at a nominal cost, it will be readily understood that the local conditions lend themselves in an exceptional manner to the requirements most desirable in the case.

In a Scotch mill, making a speciality of its wood pulp papers, the wood is treated with a bisulphite of lime solution, prepared by passing the sulphurous fumes into a tower containing the limestone, through which a stream of water is kept running. With the solution thus obtained a charge of eight tons of wood is boiled in a large rotary boiler, under a pressure of 57 lbs., for seven hours, when the pressure is lowered for a few minutes by opening the blow-off valve and allowing the volatile compounds to escape, and again increased, this time to 80 lbs. This pressure is maintained for twelve hours.

The boiled wood, after washing, is emptied into a large pit beneath the boiler, from which, after draining, it is lifted into boxes, pressed, and taken to the breaker, or washer, as it may more correctly be termed. After washing, by means of a drum, the wood pulp is emptied into a chest, from which it is pumped to flat-bottomed strainers similar to those used in connection with the *presse-pâte*. The strainer pulp is next run into the potcher in which the bleaching is conducted.

After the wood has received a preliminary bleaching the washing-drum is let down, and the chlorine compounds, formed by the action of the bleach on the imperfectly removed incrusting matters, washed out.

After this washing is completed the amount of bleach necessary to bring to a good colour is run in, and when the colour is up the wood is emptied into the draining-chests, where it lies until wanted.

The pulp produced by this process is strong, and comes to a good colour when bleached. It has, moreover, one distinct advantage over many of the wood pulps in the market, in that it comes to a soft, greasy condition with comparatively little milling, with the result that the papers made from it, especially the lighter weights, possess a strong yet silky feel.

At the present time considerable attention is being directed by British makers to the soda process, owing to the introduction and increased use of poplar pulp produced by the soda process. As is well known, American paper-makers have relied on poplar and similar soft woods for the production of papers which in this country are made mostly from esparto grass, and it is somewhat curious that poplar pulp should now be a recognised material for blending with esparto in British mills.

The methods employed in American and Canadian mills for the isolation of the poplar fibres by means of the soda process differ very little from those originally used by Watt and Burgess, excepting that the tendency is to increase the pressure and shorten the time in boiling. Owing to the very drastic action of the soda solution when employed in conjunction with a pressure of between 100 lbs. to 110 lbs., the

time employed on the preliminary processes may be curtailed considerably, the knots being so acted upon as to be easily removed by the strainers on the pulp machine. The freedom from dirt and small chips which the bleached pulp displays when being reeled up at the end of the pulp machine is very striking.

To produce a good colour on poplar pulp prepared by the soda process it is essential that the washing be sufficient to remove the combinations which have resulted by the union of the soda with the acids contained in the wood; and in order to effect this, the method employed is very similar to that used in the washing of esparto grass, as in each case it is important to ensure that complete removal of the objectionable compounds without unduly reducing the strength of the liquor to be subsequently treated in the recovery process.

The methods of boiling and bleaching vary slightly in the different mills, but as a rule a well-boiled, well-washed poplar pulp will come to a good colour with about 12 per cent. of bleaching powder.

Mechanical Wood Pulp.—A large portion of the wood used in paper-making has been subjected to no chemical treatment, and is known as "mechanical wood," to distinguish it from the pulps produced by the various chemical processes. The mechanical wood is obtained by pressing large blocks of wood against revolving grindstones, which tear the fibres from the mass. The

ground wood is washed from the stones by means of a continuous flow of water, and carried through a series of screens, in which the dirt and small chips are separated from the fibres.

Though the blocks of wood are placed so that the fibres will be torn laterally, the grinding action of the stone has the effect of making them very short, and this, together with the incrusting matter with which they are surrounded, deprives them of their felting power to a large extent.

In order to get as long a fibre as possible, the wood is sometimes steamed for ten or twelve hours, previous to grinding, that the fibres may yield more readily to the tearing action of the stone, and thus be torn at a greater length. At best the pulp thus produced is possessed of little felting power, and is not suitable for any but inferior grades of paper such as news or low quality printings.

Apart from the poor felting properties of the fibres, the lignin contained in the wood is acted on by air and light if exposed for any length of time. It is this oxidising and decomposing action which is the cause of the discoloration of paper containing even a small proportion of mechanical wood pulp.

Notwithstanding these serious defects, mechanical wood is largely used as a filling material, owing to its low price and opacity. Because of the latter property it is much used to counteract the transparency of papers made from sulphite wood. As

much as 70 per cent. is often used in the manufacture of news, and even with no other fibre than 30 per cent. of sulphate or sulphite wood a good news is produced.

TABLE OF COMPOSITION OF WOODS (MÜLLER).

	Birch. Per cent.	Beech. Per cent.	Lime. Per cent.	Pine. Per cent.	Poplar. Per cent.
Cellulose	55·52	45·47	53·09	56·99	62·77
Resin	1·14	0·41	3·93	0·97	1·37
Aqueous extract	2·65	2·41	3·56	1·26	2·88
Water	12·48	12·57	10·10	13·87	12·10
Lignin	28·21	39·14	29·32	26·91	20·88

CHAPTER V

ESPARTO AND STRAW.

ANALYSIS OF AIR-DRIED SAMPLES (MÜLLER).

	Spanish.	African.
Cellulose . . .	48·25 per cent. .	45·80 per cent.
Fat and Wax . .	2·07 „ .	2·62 „
Aqueous extract .	10·19 „ .	9·81 „
Pectous substances	26·39 „ .	29·30 „
Water	9·38 „ .	8·80 „
Ash	3·77 „ .	3·67 „

A GLANCE at the foregoing analysis will reveal that the amount of cellulose contained in esparto does not quite reach 50 per cent. That means that, given the best working conditions, 20 cwts. of esparto will not produce much more than 9¾ cwts. of paper.

Before this amount can be rendered available for paper-making, the 10 cwts. of non-available materials must be got rid of. Not only do they require to be separated from the cellulose, but they must be removed in such a manner as will prevent any recombination which would tend to injure the cellulose. Caustic soda has been found most suitable for this

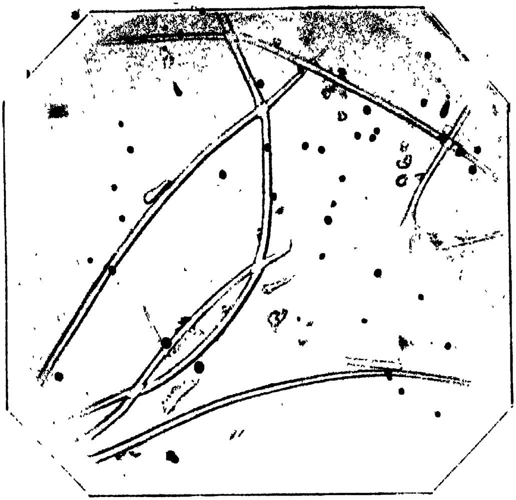

FIG. 7.—ESPARTO × 130.

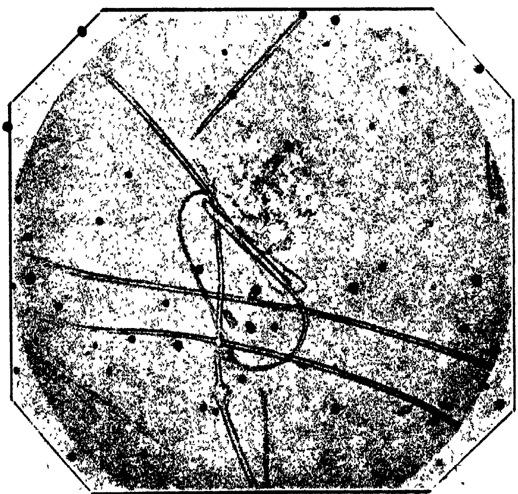

FIG. 8.—STRAW × 130.

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purpose, both on account of its reducing and combining power.

When esparto is treated with a hot solution of caustic soda, the gummy, resinous, and waxy substances, together with the silica, which forms the waterproof coating of the whole, are dissolved—the former as fatty and resinous soaps, the latter as silicate of soda. The percentage turn-out of winter cellulose will be less than of that cut in the summer, for this reason, that the winter cellulose will contain more moisture than the summer. This being so, it will require a smaller quantity of soda to boil with.

Before purchasing a supply of esparto, or in fact any other paper-making material, a sufficient quantity should always be secured to admit of a practical test being made, so that the paper-maker may know whether the amount of available material contained is in proportion to the money he has to pay for it. A neglect of this precaution, especially in a mill where large quantities are used, may and does often mean the loss of a considerable amount of money in a year.

After the bales of grass have been freed from the hoops or ropes with which they are held together, the small bundles are fed into the dusting machine, which breaks them up and dusts them at the same time.

The endless felt which receives the dusted grass

as it leaves the duster may be extended so as to deliver it right over the boiler mouth, and should be so placed that space enough is left on either side for sorters, should there be any necessity for removing knots and roots, which might become broken up by the action of the soda, and so pass through the strainers of the *presse-pâte*, and cause black or brown specks to appear in the paper.

Esparto, owing to its pectous nature, yields with comparatively little resistance to the reducing action of the soda. While it is quite possible to set free the cellulose by boiling under very low pressures, or even in open boilers, it is necessary to use strong solutions, and to extend the treatment over a much longer time than is required when the pressure employed is high.

As a rule, the higher the pressure employed the less soda is required to do the work; but this applies only within certain limits, as the use of high pressures is very liable to induce recombinations of the non-cellulose constituents which, in addition to damaging the pulp, hinder the reducing action of the soda.

If vomiting boilers are used, the work of boiling 40 to 50 cwts. of grass can be accomplished in 2½ to 3 hours, under a pressure of from 30 to 40 lbs., using 14 to 16 per cent. of 70 per cent. caustic on the raw material.

The conditions of working vary in nearly every mill, in accordance with the quality of the paper to

be made, so that no hard-and-fast rule as to temperature, duration of boiling or strength of solution, can be set down. It should, however, be borne in mind that when the grass used is difficult to bleach it is better and more economical to boil with half a pound, or even a pound, more caustic per cwt. than to use extra bleach to give the desired colour.

The additional caustic will not impair the strength of the grass unless the temperature employed be much higher than usual, while it will have the effect of softening the fibres and rendering them more easily penetrated by the bleach. Extra bleach means extra antichlor, injury to the *presse-pâte* wire, and, in a marked degree, weakening of the original strength, together with the production of much powdery fibre.

Whatever be the material treated, concentrated solutions of caustic soda perform the work much more expeditiously and effectively than dilute ones; so that a better result will be obtained by putting in as large a quantity of the material as possible, thus leaving less space to be filled up with water, than by boiling a smaller amount with a more dilute solution.

After the boiling is completed, the steam from the blow-off should be used to heat the water to be used for washing.

When all the spent lye has been run to the roaster tanks, assuming that it is to be evaporated and recovered, the grass should be treated with hot water, the hotter the better, as when hot it frees the fibres

from the fatty and soapy substances which still cling to them.

After standing for some time, this first water, as it is usually termed, is also run to the roaster and the boiler filled with clean cold water, which is allowed to remain in contact with the fibres until it is required. When this last water is run off it may be pumped to the blow-off tank, there to be heated by the blow-off steam, and used as a first water for the next boiling.

In some mills the grass is taken straight from the boiler to the potcher, where it is washed by means of a drum similar to that used for washing rags. Many paper-makers object to this method of washing, as a large proportion of the finest fibres are very liable to pass through the meshes of the wirecloth covering and be carried away with the washing water.

Very good results, both for cleanliness and yield of fibre, are obtained when the grass is washed in a system of tanks connected together in such a way that the water after rising to the top of the one passes to the other, and so on to the end of the series. The motion of the water is so slow that sufficient time is given to clean the grass without carrying away the finest fibres.

When the grass in each chest is washed clean, the pipe connecting it with the next one is closed, and the water drained away through the perforated false bottom formed of iron plates. The grass generally lies

in the chest for twenty-four hours, but can be washed much quicker when required.

Another system of washing, said to give very good results, is that of treating the grass in the boiler with cold water under pressure. The pressure is maintained by a force pump, and the outlet is into a tank above the boiler. This water can be heated and used to wash the next boiling.

In some mills the grass is washed in the boiler by blowing a blast of air into the water, and thus creating sufficient agitation to free the fibres from the non-cellulose substances which still cling to them. In this way a boiling can be well washed in four hours when the water is changed three or four times. The chief advantage of washing in the boiler lies in the saving of time and labour effected, as compared with the washing in tanks.

When steam is used to aid in bringing up the colour great care must be taken not to overheat, or the strength will be impaired and the colour go back. Eight cwts. of grass, reckoned on the raw material, should be perfectly bleached in about 2 or 2½ hours with about 8 per cent. of bleach.

The bleach should be run in with the water while furnishing, and when full the steam should be turned on. When the heat is up, which will be in about twenty minutes, it should be turned off. The steam cocks should be perfectly tight, as if they allow steam to pass when shut the grass will be in danger of being

overheated; and this is especially so when it is left standing in the potcher for any length of time. The same care must be taken in using the antichlor, as is necessary with rags, that no excess be present.

It is the practice in some mills to run the grass over the *presse-pâte* before bleaching, so that the wire may not be damaged by the acid set free when the antichlor decomposes the bleach. Unless the grass has been properly boiled, the roots and hard ends will not yield to the action of the bleaching solution, and owing to the hardness of the fibres they will not go through the plates of the *presse-pâte* strainer.

Though the percentage of cellulose contained in straw is nearly as high as that from esparto, the yield of available paper-making material is not so high. Owing to the chemical and physical characteristics of straw, it requires to be boiled with a larger proportion of soda than is necessary for esparto. The compound cellulose, which constitutes the basis of the straw plant, contains a greater proportion of lignin than the esparto cellulose, and ligno-cellulose is much less susceptible to the reducing action of the caustic than pecto-cellulose.

In addition to this, the knots must be so reduced in boiling that the bleaching solution will be able to saturate them without using an excessive quantity. The effect of this extra soda is that the finest fibres are liable to be carried away with the washing-water, and thus the yield is often as much as 10 per cent. less than that from esparto

Straw is usually boiled in rotary boilers, as by using them the pulp is so reduced as to run through a pipe into the steeping tanks, and thus the lifting from the boilers is saved. The boiling pressure is also higher than for grass, fifty to sixty pounds being often employed.

The boiled straw may be washed in large cement-covered tanks, and after draining be dug out and taken to the potcher to be bleached in the ordinary way. When it is to be used in the mill it may be run straight to the bleaching house to drain until wanted, but it is usually run over the *presse-pâte* in the same way as grass.

Papers made from straw are, owing to the hard nature of the ultimate fibres, very hard and brittle. This want of flexibility is as much owing to the smooth, highly-polished surface of the fibres, as to their shortness and stiffness. When 5 or 6 per cent. of good, clean straw pulp is used, the paper gets a firmer grip and rattle.

Straw also helps the sizing, probably owing to the pores of the paper being filled up with the fine fibres, as much as to its hardness, but it is not suitable for papers which are wanted to bulk well.

ANALYSIS OF STRAW (MÜLLER).

	Winter wheat.	Winter rye.
Cellulose	46·60 per cent.	47·69 per cent.
Fat and wax	1·49 ,,	1·93 ,,
Aqueous extracts	8·07 ,,	0·05 ,,
Non-cellulose or lignin	28·49 ,,	26·75 ,,
Water	9·85 ,,	11·38 ,,
Ash	5·50 ,,	3·20 ,,

CHAPTER VI.

BEATING.

It is an accepted principle that in order to produce a paper which will have strength and tearing strain the fibres must be kept long in the beater; and more especially does this apply to such thin papers as banks and loans. While it is quite true that long fibres do give these qualities to the papers made from them, it is also true that the fibres may be kept long and yet the paper produced possess less firmness and tensile strength than if they had been kept finer.

Whether the fibres be long or short when they reach the machine, the properties of the paper made depend on the treatment they receive during the first hour-and-a-half in the beater. If the roll be put sharply down on the plate at first, the fibres, while still retaining their length, will become weakened, and the sheet will have a raw, soft feeling, which even the addition of more than the usual amount of starch will not overcome.

Such stuff is generally termed "fast" or "free"

and though for certain classes of papers, such as thick chromos and lithos, the thickness of which renders strength and firmness in the ultimate fibres a matter of less importance, free stuff is desirable, yet the beater-man should try to temper the stuff so as to preserve as far as possible the original strength and elasticity of the fibres.

The rawness referred to is also very noticeable in papers made from esparto, to which have been added 1 or 2 per cent. of strong rags. In the beating of such stuff, especially if the paper be thin, the idea that length means strength is often so much developed that when the pulp reaches the strainer a large proportion of the rag stuff refuses to go through.

A little consideration of the subject will show that the behaviour of the fibres under the influence of the shake, as they are carried along the wire, has a great deal to do with whether the sheet be strong or the reverse. If a sheet of thin paper be placed under the microscope, it will at once be seen that there exist between the fibres spaces which seem to be filled with some transparent non-fibrous material.

The longer the fibres the more apparent do the spaces become, and, however minute, their presence must tend to weaken the sheet. When the fibres are a shade finer, the finest of them will, under the influence of the shake, settle down into these spaces, thus making the sheet more closely felted.

This is the reason that, when using broke from the

edgerunner, so large a proportion of the loading is carried in comparison with the amount retained when no broke is used. Edgerunner broke is generally reduced to such a state of fineness consequent on its having been under the action of the roll so often that it floats on the surface when on the wire; and in addition to the shake, the suction of the pumps tends to draw the very fine fibres which compose it into the spaces referred to.

In filling up these spaces, not only do the fine fibres greatly assist in making a close and evenly felted sheet, but by their presence they also prevent the loading materials from passing through the meshes of the wire as they would otherwise be very liable to do.

It is in the making of such papers as banks and loans that the ill effects of keeping the stuff too long become most apparent; and this is especially the case if the strainer plates used for the ordinary fine stuff are expected to take through the long rag stuff equally well.

The rubbing of the plates which is essential in such circumstances, in order to keep them from clogging up altogether, has the effect of completely spoiling what would under other conditions be a clean, strong sheet, by peppering it with dirt and knots. Only those who have had the working of such stuff can fully appreciate the improvement which a finer engine will make in regard to the appearance and strength of the sheet.

It will be more mellow, strong, and clean, and not

least of the advantages derived will be the giving of more time to the machine-man to run steady weight, unhampered by the flooding and thinning which are unavoidable in such a case.

In preparing stuff for thick papers, such as chromo and litho printing, the roll must be put down from the first, that the stuff may be fine and free, and so part with the water easily and give a close, evenly felted sheet. To insure that the stuff will not be too soft, it should not run more than three or three-and-a-half hours in the beater.

Stock intended for thin, strong papers must be drawn out and milled in the washer for at least six hours, and in the beater for ten or twelve hours. Blunt plates and rolls are necessary for the milling of such stuff, as a sharp plate or roll would cut it up too much, and, making it free, prevent it from softening properly.

In preparing long greasy stuff, intermediate beaters possess this advantage: that by having blunt plates and rolls in the first engine, the stuff is milled in such a way as to render the fibres long and flexible, and capable of imparting a soft, silky feel to the papers made from them; while in the second engine they can be reduced to the required length when they are in such a condition owing to the first treatment that the cutting action of the sharper tackle will not impair their strength.

Several engines having the same end in view are used

in American paper-mills; and one of these beaters, or "perfecting engines," as they are termed, is becoming pretty well known to paper-makers in this country under the name of Marshall's perfecting engine. The author was running the machine to which it was attached when first tried in the mill where he served his apprenticeship, and had therefore a good opportunity of judging its merits.

The engine consists of a conical cylinder, the inside of which is fitted with steel bars in much the same manner as the bed-plate of the beating engine. Inside this cylinder a conical roll, also fitted with steel knives, revolves at a high speed, and as the stuff passes between the roll and the bars on the inside of the cylinder, it may be reduced to any degree of fineness. On reaching the end of the shell the stuff is made to pass between a revolving and a stationary disc, both of which are fitted with knives.

The action of this disc or brush, as it is called, serves to rub out all knots and chips in much the same way as does the rubbing of the roll in the ordinary beater. This beater possesses all the advantages of the intermediate system, while requiring much less space and driving power compared with it.

In the preliminary treatment necessary in the ordinary beater, before passing the stuff through the perfecting engine, the roll should be let down to a little more than a rub—just sufficient to mill the stuff is all that is required. When emptying to the chest,

from which the perfecting engine is supplied, much less water must be put down than is usual when emptying to the machine chests; the reason for this being that the thicker the stuff is in its passage through the engine the better does it accomplish its work.

As the pulp after passing through the engine flows into the machine chests in a continuous stream, the weight is more constant; and when it does alter one way or another it does so very gradually, thus insuring that the machine-man will notice and correct it before it can have much effect on the sheet. If the pulp contains a large proportion of grass, it should be diluted by running in a stream of water as it leaves the perfecting engine, and thus prevented from running into knots in the chest.

When the stock consists of materials which are not fitted to bear the same beating strain, it is better to beat them in separate engines. Of course it is not always convenient to do this, especially when the proportion of strong or weak stock is small. To treat such a small proportion separately would keep back the other engines too long, in addition to changing the proportions in the finished sheet.

In order to reduce good Spanish grass to fine stuff, it requires a firmer treatment with the roll than most of the rags which are mixed with it would get if treated in a separate engine, and this should be taken into account when selecting the rags to be used along with it. When the stock consists wholly or in large pro-

portion of chemical wood, the engines must not be heavily loaded nor allowed to run long in the mill, as the wood is reduced very easily and soon becomes greasy.

For medium weights of all wood-papers three hours is quite sufficient, and for the lightest weights eight hours. When it is especially desired that the paper should not crack when folded the time may be extended to six hours; but in that case the machine will have to go slower in order to allow of the water being taken out. Some wood pulps, however, are much more difficult to soften than others, and even after milling for a considerable length of time still tend to be free. This is in all probability due to the treatment in boiling or bleaching, or perhaps in both, having been too drastic, with the result that the natural elasticity of the fibres has been impaired.

When making unsized papers it will be noticed that the sheet tears much better than a sized sheet from fibres of a similar fineness will do. This affords conclusive evidence that, within certain limits, it is the flexibility and softness of the fibres, more than their length, that give tearing strain to a sheet.

The unsized fibres are not coated with the resinate of alumina used to size with, and therefore retain their natural elasticity and tensile strength. When under the action of the shake the unsized fibres are more closely felted than would be possible were they stiffened by the size-coating, and this is more notice-

able if the sheet be torn across the wire instead of down its length.

When a sheet of paper is torn the fibres are not broken, they are simply pulled asunder, and it is for this reason that it always "skins" better when torn down the wire than across its length. Stuff for blotting-papers must be cut up as quickly as possible in the beater, and run not longer than an hour and a half in the mill. The beater must be light loaded, and the stuff kept constantly travelling, otherwise it will not have a uniform absorbing-power.

Soft cotton rags are generally the stock from which blottings are prepared. Manilla hemp, owing to its soft, lustrous nature, and the width of the central canal, should, with proper treatment, be possessed of good absorbing qualities.

Whatever be the shape or size of a beater, it must be so constructed that no stuff will lodge in any part of it, and for all-round work it must have a roll heavy enough to thoroughly soften the pulp and keep it in constant motion. If a beater of large capacity is desired, Forbes's patent double-roll beater possesses all the requirements, with the exception that the rolls are not heavy enough; but with heavier rolls, and the speed of the lifter no faster than is necessary to ensure good travelling, the pulp produced will be of a very uniform character.

It is the practice in some mills to wash the inside of the beating engines with soda ash, and even caustic

lye, when changing colours, with the result that the smooth skin, which coats the sides, is rendered quite rough. This roughness retards the passage of the pulp in a way that is almost incredible to those who have not witnessed its effects. Not only does such washing interfere with the travelling, but it is the worst thing possible for causing rust spots to appear in the paper.

Under none but the most exceptional circumstances should the rolls or sides of the beaters be subjected to any washing or scraping which will tend to break up the enamel-like surface which, if let alone, the continual contact with the moving stuff, and the chemicals contained in it, will impart to them. Under the ordinary conditions of working, beater-rolls should run from eighteen to twenty months after filling, and bed-plates from ten to twelve weeks.

Should the plates be worked for a longer period than that, the roll has to be put so firmly down, in order to make fine stuff, that the driving power is taxed to the uttermost, and, in addition, the stuff, from having to be kept a much longer time in the engine before it can be made fine, is very liable to become too soft.

As a result of the increased demand for the cheaper grades of paper, consisting wholly or in large part of wood pulp, the tendency in beater construction has been towards the production of beaters of larger capacity; and no doubt, when it is possible to arrange

for long runs on one grade of paper, these large engines possess several distinct advantages.

The colouring of a larger body of pulp at one time tends to regularity and the prevention of shades, while the pulp is much less apt to become too greasy, owing to the fact that it has much further to travel between each contact with roll and plate. The necessity for the production of free stuff which will allow of quick driving and a close even sheet has led several paper-making engineers to design beaters in which the roll is placed so as to be quite clear of the pulp, the latter being supplied in some instances by means of a screw, and in others by a circulating pump. Perhaps the most popular of these new types is that known as the "Hibbert" beater, which also combines the beating and refining, and has been largely adopted in mills making long runs on wood pulp papers.

It must not, however, be assumed that, because for certain grades of wood pulp or esparto papers the newer type of beating engines offer advantages, the Hollander type has been rendered obsolete. The fact is that the tendency to specialise is becoming much more noticeable, with the result that makers, having proved that a certain type of beater suits the special papers to which they are turning their attention, are installing the particular beater when opportunity offers.

The problem which confronts the paper-maker when called on to decide on the type of beater to adopt must depend for its solution on the special require-

ments of the paper he desires to produce, and the power at his disposal for beating purposes, together with the physical properties of the raw materials to be employed. In order to produce from, say, esparto, a pulp which would be capable of settling down quickly on the machine wire, and making, under the influence of a medium shake, a close, mellow paper—which, in view of economical production, must be turned out at a quick speed—the roll and bed-plate bars would require to be somewhat sharp, in order to shorten the fibres sufficiently without rendering them so greasy as to retain the water too long on the wire. The circulation must also be well maintained, and for the preparation of such papers the new type of beater offers distinct advantages, as, with the independent circulation, it is possible to arrest the flow of the pulp when it is fully prepared, and thus avoid getting it too greasy.

Most practical paper-makers will be ready to admit, however, that a beater which is eminently fitted for the production of fine, free stuff, will not of necessity produce as good results, even under skilful manipulation, when working on, say, chemical wood pulp for the production of a paper such as the thin Kraft papers, in which the indispensable requirements are toughness and flexibility, together with the mellow appearance characteristic of well-milled greasy stuffs from the Hollander type.

Notwithstanding the degree of nicety with which the roll can be raised or lowered, and the means

thus at hand for regulating the superficial pressure exerted on the ultimate fibres as they pass between the bars of the roll and the bed-plate, the pulp produced with sharp bars is invariably weaker, and (though the ultimate fibres may be a fair length) lacks the greasy well-milled feel which is indispensable for the production of thin, tough papers. This inferiority is all the more noticeable should the stock consist of strong rags and wood pulp, as the already disintegrated wood fibres are too much cut up by the treatment necessary to open out the fibre bundles of the rags. It is well known that a light beater roll will draw out the fibres much better than a heavy one, but that, in order to produce equal results in the reduction of the fibres, the light roll will take longer time. The whole question really lies in the superficial pressure exerted by the roll, and with sharp bars the pressure is increased in proportion as the area of the bearing and cutting surface is reduced.

For the production of the higher grades of writing and printing papers, in which the appearance is so important a factor, the best results will be obtained with bars about one-sixteenth of an inch on the face. This will be found to hold good whether the half-stuff consists of rags, esparto, or wood; and as the demand for cheap, smart-looking papers seems to become more pronounced, such conditions are likely to govern the type of whatever innovations may appear in beater construction. It will be generally admitted that for

good all-round work the medium size of beating engine, carrying from 500 to 700 lbs. of stuff, is undoubtedly the best, although, as mentioned above, beaters of larger capacity possess certain advantages for long runs on one quality of pulp.

While no hard-and-fast rule as to the conditions of the bars can with any safety be promulgated, it will be of material assistance to paper-makers who wish to determine the most suitable conditions of roll and bed-plate bars, for the treatment of any particular half-stuff, if they will set to work and find out the exact relationship which exists between the state of the bars and the amount of superficial pressure exerted between them when in contact with the stuff. To state the matter crudely, the smaller the area of the points of contact, the greater the pressure exerted on the fibres, and *vice versâ*.

With a view to testing the difference produced on wood pulp papers by beating the fibres under a low superficial pressure, the writer has substituted a solid block of granite for the usual bed-plate of steel bars, with excellent results. The experiment was first tried with a beater of the usual Hollander type, carrying from 450 to 500 lbs. of pulp, having a roll 42 inches on the face, with 72 bars drawn out to one-eighth of an inch on the face. The plate contained 26 bars, also one-eighth of an inch wide on the face. The granite block gave a bearing surface of 42 inches by 8 inches, and was hollowed out to suit the sweep of the roll,

with the result that the ultimate fibres were drawn out, as they were swept across the granite face by the action of the roll bars.

By substituting the solid block the superficial pressure is thus reduced to about one-third, while the number of cuts per revolution of the roll is now 72, as against 1872 with the steel plate.

The advantage gained in beating half-stuff, which already contains a sufficient number of short fibres to impart the desired firmness to the finished sheet, without the necessity of further shortening them, is very considerable. After a trial extending over a period of eighteen months, the net results of preparing stock, which is wanted long and tough, under the lower superficial pressure, and with the cutting power so much reduced, showed an increase of 30 per cent. in the strength and firmness of the papers produced, together with a very considerable increase in the turn out, due to being able to get the stuff out in a shorter time. Originally intended to draw out sulphite wood without cutting it, the method was tried experimentally on strong rag stuff, and with such good results that it was adopted for beating fibrous materials, such as strong cotton and linen rags, hemp, and jute. The increase of strength is most noticeable when the furnish consists of a mixture of fibres which present a variety of characteristics as to length and resistance to the knives, as the weaker fibres are not rendered too short before the stronger ones are sufficiently drawn

out. This increase in the strength of the finished sheet was so marked in one instance, that when the machine started up with the stuff prepared under the new conditions the paper was considered so much above the usual quality that an additional quantity of loading was added to bring it to the desired standard.

Not the least advantage in working the solid block is that the stuff from strong materials can be cleared much better; and though the individual fibres retain their original length in a much larger degree, this freedom from knots has the result of making them pass through the screens much more readily than fibres which have been cut short without being sufficiently drawn out and set free from the fibre bundles, as is often the case when long stuff is prepared with even moderately sharp tackle. When the block is made to fit the "den" exactly, it becomes a very simple matter to substitute a block for a plate, or *vice versâ*, should the particular requirements of the paper it is desirable to produce render it advisable. Should the blocks become worn smooth, as they do in time, it is well to have them picked on the surface, as in this way they retain the stuff better, and the beating can be accomplished in shorter time.

When tried against steel plates, the writer found that with rough blocks a better quality of paper could be produced in six hours than could be obtained in eight hours from steel plates.

CHAPTER VII.

LOADING.—STARCH.—COLOURING MATTER.

Loading.—It is not an uncommon idea with a great many people that, in adding loading materials to the paper in the process of manufacture, the paper-maker is actuated by a motive akin to that which prompts the dairyman to water the milk.

Though the percentage of loading in some papers would seem to justify such an opinion, yet, as a rule, the loading is added with a distinct view to making the paper more suitable for the particular purpose to which it is applied. In the case of printing papers especially, the addition of 15 or 16 per cent. of loading, by making them more absorbent, enables them to print much better, and lessens in a considerable degree the friction when in contact with the types.

The first thing that the paper-maker must take into consideration when selecting a loading material is that its chemical nature is such that when in contact with the free acids or chlorine compounds, liable to be present in the pulp, no chemical or physical change

will result. When that has been satisfactorily settled, the next requirement to be looked to is freedom from sand or coarse particles, which would tend to impair the value of the paper; and lastly, the colour should be bright enough to blend with the shades of paper for which it is intended.

Kaolin, or china clay, as it is usually termed, is the loading usually employed in the making of news, printings, and the lower qualities of writings. The clay is made into a thin cream with water, generally in a chest fitted with a revolving agitator, so that when furnished to the engine it will always be of the same consistency. Some paper-makers mix it with resin size, the idea being that in this way it is more firmly held by the fibres, and less liable to pass through the meshes of the machine wire.

Before running into the beater it should be carefully strained, so that any sand or unground particles may be kept back. The sieves used for this purpose should be very fine, as even the best grades of clay contain a considerable proportion of extraneous matter.

China clay, in addition to enabling the paper loaded with it to take up the printing ink more rapidly, helps materially in bringing up the surface when calendering, though from its power of absorbing moisture the high finish thus obtained is liable to go back if exposed in a damp atmosphere. Should an excessive amount be added, or if it has been imperfectly strained, the pressure of the calender rolls will have the effect

of squeezing the coarser particles out and leaving the sheet pierced with innumerable very minute holes.

The sizing and feel of clay-loaded papers are never so good as with papers loaded with such materials as pearl hardening or barium sulphate, nor do they bulk so well. Heavy chromo and plate papers often contain as much as 35 to 40 per cent. of clay; and though such a large amount is very apt to cause "dusting" in cutting and printing, the impression obtained is much more clear, and the colours are absorbed more rapidly, than would be possible with a smaller proportion of loading.

For the better qualities of writing papers, the materials used are calcium sulphate, sulphate of barium, barium chloride, and agalite.

Calcium sulphate—or pearl hardening, as it is usually named—is generally clean enough to be added to the engine without straining, and is added in the dry state, and owing to its firmer nature the sizing is much less impaired than with clay. In addition to its hardening properties, it imparts a purity of shade to the paper, which makes it very valuable as a loading for the finer qualities of writings, in which look is of the first importance. This brilliancy is also possessed by barium sulphate, but as it is not usually so free from dirt it is not so suitable for high-class papers.

Barium sulphate, owing to its high specific gravity, is not carried so well by the stuff, and when diluted

to the consistency usual in the sandtrap, a large proportion settles out and adheres to the bottom of the spouts. This, together with the amount which passes through the wire and is deposited on the bottom of the save-all, reduces the percentage carried to about 30 per cent. of the amount actually added. It should be mixed with water and strained before being put into the engine, otherwise a large amount of dirt will be carried into the paper.

A paper, weighing equal to about 40lbs. demy, when loaded with clay to show 19 to 20 per cent. on burning, will carry as much as 85 per cent. of that added to the beater. Should such a paper consist of a large proportion of edgerunner broke, the amount carried will in some cases be as much as 90 to 95 per cent.

It must be borne in mind, however, that when edgerunner broke is used, the amount added to the engine will contain as much as 15 to 18 per cent. of clay firmly fixed on the fibres by the previous sizing and drying, so that the percentage of that added as clay, which is carried in the paper, is not so high as it at first appears. Heavy chromo papers burning 35 to 40 per cent. of clay will not carry more than 50 per cent. of the amount added.

This is owing to the beating of the stuff, which is cut up very quickly and thus rendered very free, coupled with the fact that the machine wire in

travelling so slowly gives more time for the loading to be shaken through the meshes. The percentag of barium sulphate carried will seldom exceed 35 per cent., while pearl hardening will usually turn out 50 per cent. It is claimed that by using chloride of barium, and adding a slight excess of alum or alumina, sulphate of barium will be precipitated on the fibres in such a way as to enable them to retain it much better, and so increase the turn out.

Agalite is the only loading material apart from ground wood which can claim to be more than a loading, on account of its fibrous nature.

Agalite is prepared from asbestos, and retains the fibrous nature of that substance. Owing to this the loss in passing over the wire is much less, and indeed it is claimed that in ordinary circumstances as much as 99 per cent. is actually carried. By using agalite the surface is much improved, owing to its soapy nature, and the sizing is not impaired as with china clay.

It has the drawback, however, of making the paper loaded with it very greasy, owing to the size having become fixed in the pores, and retaining the water very obstinately.

Starch.—This is applied to papers in the process of manufacture for the same reason as it is used by the housewife in preparing collars and cuffs for ironing

and glazing—namely, for hardening, and enabling them to resist the effects of moisture, as well as for imparting a high polish in the subsequent glazing process.

In some mills it is the custom to boil the starch with the resinate of soda solution before adding it to the pulp, as in this way a larger percentage is retained by the paper. When applied in this way, the paper, though taking on quite as good a surface, has not the firmness and rattle obtained when the starch is added to the pulp in the dry state, or merely dissolved in cold water, that the impurities liable to be contained in it may be kept back by putting it through a fine wire-cloth sieve.

Colouring Matter.—Notwithstanding the purity of colour that can be obtained by a judicious use of the bleaching solution, very few even of the finest qualities of white papers are made a "self-colour." The colours used for brightening or enriching the majority of cream coloured papers are ultramarine and carnation. In order to ensure uniformity of shade, a certain standard should be fixed for each of these colours; and thus, by comparison, the colouring power of new brands which may from time to time be brought in can be at once determined. The standard sample may either be prepared by mixing a known quantity of the colour, decided upon as the standard, with a measured quantity of fine starch or pearl hardening;

or by dissolving a small portion in hot water, and saturating narrow strips of white blotting paper with the resulting colour.

By treating equal weights of the new samples in exactly the same manner, taking care always to preserve the same proportions when dissolving, an accurate idea of the relative colouring power can at once be obtained, and a short calculation, based on the amount of pulp coloured by the standard, will enable the papermaker to determine whether the colouring power of the new sample is in proportion to its cost.

The behaviour of ultramarine—or, to use the best-known name, blue—with the alum solution used in the mill, should also be ascertained, by allowing a drop to remain in contact with a diluted solution of alum or sulphate of alumina for a sufficient length of time to show whether the colour would be affected during the contact necessary in the beaters, machine chests, and sizing tub.

Blue should always be dissolved in hot water and carefully strained before adding to the pulp, so that no insoluble particles may be fixed on the fibres, and appear as blue specks on the under side of the sheet. To ensure that the colour will be uniformly distributed, when a considerable quantity is being used, half of the amount necessary should be put in just after furnishing, so that it may be thoroughly mixed, while the remaining half should be added as

soon as it has been ascertained whether any alteration is to be made.

Pulp which has been left standing in the machine chests for any length of time will generally be found to have gone back in the colour when blue is the colouring matter used. This fading will be greater in proportion to the amount of acid contained in the pulp, the exposure to light to which it has been subjected, and the amount of iron impurities contained in the water or communicated from the rolls and sides of the beaters.

In some mills the amount added, in order to counteract this fading, when the pulp has been standing from Saturday night until Monday morning, is equal to a third of the colour used to give the desired shade, while in others a sixth is found to be sufficient. When making papers coloured with smalts, which is unacted on by acids, the fading is very slight, about a half-pound for every twelve pounds left in the chest being quite sufficient. With inferior grades of smalts the liability to fading is, however, much greater.

When making delicate colours the alum should be kept out until just before drawing the valve, so that the contact with the colour may be as limited as possible. A very suitable way in which to use cochineal is to dissolve it in a dilute solution of ammonia, to which a little cream of tartar has been added. The cochineal paste is sometimes dissolved, with the cream of tartar, in the water before the ammonia is added. Used in this way there is no danger that the colour

will spot the underside of the paper, as is often the case when the dry carnation powder is used.

Not unfrequently when making toned papers the iron used to give the shade makes the resulting colour too bright. In such a case a glass or two of bark liquor added to the engine or the chests will deaden the colour to the desired shade.

When making greens, which colours are usually produced by combination of bichromate of potash and nitrate of lead with Paris blue—or paste blue, as it is often termed—the two first mentioned should always be put into the engine and allowed to become mixed with the pulp before the blue is added, and alum should be kept out until just before drawing the valve. Before adding the nitrate of lead to the engine care should be taken that there are no traces of chlorine compounds in the pulp, as the presence of such would cause the yellow colour produced on the addition of the bichromate to take on a dull orange tint.

Aniline Colours.—Though the advantages attending the use of the coal-tar derivatives or aniline dyes—to give them their most familiar name—have been known for many years, it is only within a comparatively recent period that these dyes have been used for colouring any but the cheaper grades of paper. Thanks, however, to the painstaking and elaborate investigations of the German chemists, applied under "up-to-date" commercial conditions, these coal-tar colours have been

produced in an almost endless series of shades, many of which can compare favourably with the older forms of colouring matter as to stability, while for depth and variety of shade they far surpass them.

Notwithstanding that from a chemical point of view the various colours are divided into distinctive groups, named respectively *acid* and *basic*, their action is not complicated to any extent. As a rule, when using the comparatively small quantities necessary for tinting purposes, it will be found that both the so-called acid and basic colours will give reliable and regular results when fixed with any of the alum compounds in general use; and this fact alone is sufficient to ensure the adoption of these aniline dyes in most mills. It is when using the larger quantities necessary to produce the deeper shades that regard has to be given to the reaction peculiar to each derivative, inasmuch as a considerable advantage, in point both of economy and of regularity, is gained by taking advantage of these distinctive properties. Thus, when making a deep scarlet, better results are ensured if the pulp be first dyed with a basic colour such as paper scarlet, and subsequently, after allowing time for complete mixing, an acid colour such as cotton scarlet be added. By proceeding thus, the acid colour forms a chemical combination with the basic dye, with the result that a precipitate is formed on the fibres, ensuring a fast colour and more complete exhaustion, with the attendant advantages of a much clearer backwater.

Of the acid group, cotton scarlet is perhaps the best known, and being largely used for the production of deep shades, the question of complete exhaustion and a clear backwater is of the first importance, in view of the avoidance of pollution difficulties. Notwithstanding that a great many experiments have been made in order to determine the conditions most suitable for ensuring a clear backwater when using large quantities of cotton scarlet, the fact remains that it is practically impossible to do so, even when the utmost precautions are taken to ensure the formation of a lake precipitate on the fibres. It will be found, however, that by observing certain precautions a great degree of exhaustion may be obtained; and one of the most important points is to allow sufficient time for complete mixing of the pulp and the dye before adding the sizing solution, care being taken to add about twice the usual amount of sizing.

Fresh dyes, it will be found, are much more liable to give rise to frothing than if the lids be removed for some time. When using paraffine for froth prevention, care must be taken to avoid an excess, as otherwise small specks of tarry matter will appear in the sheet.

As a rule the acid colours will be found to have more resistance to light than the basic colours.

Auramine may be taken as typical of the basic group, and gives excellent results, either used alone or in conjunction with other colours. When using colours belonging to the eosine group, great care must

be taken to maintain the temperature of the drying cylinders as uniform as possible, as otherwise a considerable variation of shade will result. This variation is most noticeable when making delicate shades on the single-cylinder machine.

Dyeing to Shade.—As a general rule, the dyeing of paper pulp is conducted in a somewhat haphazard manner, with the result that, while in the greater number of instances the methods adopted by the papermaker work out fairly well, it not infrequently happens that much time is lost and paper spoiled through the colours not being right in shade; especially should the shade be a new one for that particular mill. Given even an elementary knowledge of the nature and properties of the dyes to be used, there is no reason why any great degree of uncertainty should exist as to how the colour will work on the machine, provided that the dyeing be carried out systematically and intelligently. There are two methods by which the "striking" of colours may be carried out much more expeditiously, and with (what is even of greater importance) more certainty, than is possible under the rule of thumb generally adopted.

To carry out the first of these methods, the apparatus necessary consists of a chemical balance, a graduated burette, three or four beakers, and about half a dozen stoppered bottles. For the second method the balance is all that is absolutely indispensable, though the use

of a small mortar and pestle facilitates matters a great deal. In carrying out the first method, which is restricted to dyes as distinguished from pigments, a weighed quantity of each dye of which it is intended to make up a standard solution is dissolved in a known volume of water and labelled in the following manner, according to the proportions of water and dye used: thus, "100 C.C. = 1 gramme" would be the label should 10 grammes be dissolved in one litre of water. In working out this method a certain number of cubic centimetres are added to a known weight of pulp—say sufficient to weigh 10 grammes when made into paper—and when the requisite dyes are added the pulp is diluted, and tried either in the hand mould or along the machine wire, when the percentage of each dye can be at once ascertained. In working out the second method, the dyes or pigments are weighed off and added to the experimental quantity of pulp in the dry state, a convenient scale being ·01 grammes of dye to 10 grammes of paper, being equal to one pound of dye to 1,000 pounds of paper. It is obvious that these experimental trials can be carried out before the time for furnishing the beaters, and so there is no unnecessary delay, in addition to securing a much more satisfactory start than is possible when the beaters have to be dyed up experimentally.

Of the two methods the writer always uses the latter, which lends itself either to the use of dyes or pigments, and when carefully worked is most reliable.

CHAPTER VIII.

RESIN SIZE AND SIZING.

Of all the materials used in the manufacture of paper, there is none about which there exists such diversity of opinion, both as to its preparation and subsequent action, as that of resin size.

Dr. Würster holds that the degree of sizing is proportional to the amount of free resin deposited on the fibres. Other experts, however, claim that the active sizing agent consists of the resinate of alumina, formed when the resin soap is decomposed by the alum; while it is asserted by some that it is a mixture of both which constitutes the size coating.

In support of the free resin theory, it is claimed that paper can be sized without the use of alum or alumina by making use of sulphuric acid to decompose the resinate of soda and liberate the resin. Though the majority of paper-makers hold the opinion that the resinate of alumina alone sizes the paper, nearly every mill has a different recipe for the preparation of the size.

While the exact chemical composition of resin is still a matter of some obscurity, chemists and paper-making experts are generally agreed that two parts of crystal soda are required to unite with four parts of resin; while, if good soda ash be used in place of the crystal form, one part will form a neutral resinate with four of the resin.

The following recipe will give a reliable size of a light brown colour, which will be as near as possible a neutral resinate of soda:—Dissolve ninety-eight pounds of good soda ash in thirty-six gallons of boiling water, and then add four hundred and twenty pounds of powdered resin.

The best form of boiler is a jacketed one, as by using it the increase of water, due to the condensation of the steam used to boil with, is avoided. The resin should be roughly powdered by the hand, as it is asserted that the finely divided resin, prepared by using a grinding mill, is very liable to form clots on being put into the hot soda solution. So long as any of the resin is undissolved, the carbonic acid, evolved as it enters into combination with the soda, will cause the solution to froth up, and, if not carefully watched, so as to check the steam in time, it will come right over the top of the boiler.

To avoid this as much as possible, the temperature should be kept no higher than is necessary to dissolve the resin in a reasonable time. In addition to preventing the frothing, it is said that the carbonic acid,

when not violently expelled, has the power of forming a bicarbonate with the uncombined soda, which tends to improve the sizing properties of the soap.

When all the resin has united with the soda, the steam should be shut off, as further heating impairs the strength of the size. To test whether the resin has all gone into combination, a little of the size should be taken out and poured into a pailful of tepid water. If it is right it should dissolve at once, and on putting in the hand there will be no deposit of resin. If, however, the resin has not all gone into solution, the hairs on the back of the hand will be rendered quite sticky by the adhesion of the uncombined particles.

If a further heating does not serve to combine the resin, it may be inferred that, probably owing to a variation in the strength of the soda, the amount used is insufficient, and more will require to be added until the test shows that there is no more uncombined resin present. The soap should be run through a sieve before being put into the store tanks, that any insoluble impurities may be removed.

Size prepared in this way will not yield much lye when kept for a length of time, for this reason, that it does not contain much soda in excess. The lye which separates out contains the colouring matter of the resin and any soluble impurities that may have been introduced while boiling. This lye should be carefully skimmed off, and while most paper-makers make no further use of it, it is recommended by others to be

used in dissolving the next boiling, as by using it less soda is required. They further assert that the acid which constitutes the colouring matter tends to improve the value of the size.

A size prepared with the proportions given above should yield about ninety-six gallons of undiluted soap, each gallon containing nearly five-and-a-half pounds of resinate of soda. To prepare the solution for the beating engine, eight gallons of this strong size should be diluted with eighty gallons of water, which will be equal to half-a-pound of resinate of soda per gallon as furnished to the engine. After having been brought to boiling point, the size thus diluted should be strained through flannel, laid over a fine sieve, before being run to the beater store tank.

By using soda-ash and resin, in the proportion of one part of soda to eight parts of resin, a white size containing a considerable amount of free resin will be produced. A suitable way of making this white size is to boil forty pounds of soda-ash with two hundred and seventy pounds of resin in about sixty gallons of water, and when all the resin has been dissolved to add fifty pounds of finely powdered resin. When such a size is diluted for the engine, it should be of a bright white colour, owing to the amount of finely divided free resin which it contains.

When in contact with the pulp, this resin becomes attached to the fibres in a purely mechanical way, and this, together with the tendency of unprecipitated resin

to form resin spots in the paper, would lead one to conclude that, whatever the advocates of free resin sizing may think of it, the maker of fine grades will best forward his own interests by seeking to perfect the preparation of a neutral resinate of soda. Apart altogether from the composition of the sizing solution used, whether the paper be well sized or the reverse depends, to a great extent, on the mode of treatment in the beater.

When the engines are heavily loaded with as much stuff as possible, the ultimate fibres do not come under the cutting action of the knives, owing to the body of stuff between the roll and the plate, and thus, though well hammered out, the original form and elasticity of the fibres are preserved. Stuff prepared in such a manner will size well for two reasons, which will be readily understood.

When such stuff is carried down the machine wire it retains its water very obstinately, and thus the size coating is well felted among the fibres before the water is drawn out by the pumps. The loss of size with the backwater is therefore very small. The strength and flexibility of the fibres enable them to felt closely when coated with the resinate of alumina, and thus a strong, well-sized paper is produced, with the usual amount of alum and size.

With light engines the body of stuff between the roll and the plate is much thinner, and thus the cutting action is more drastic. The result is that,

in addition to being reduced in length, the fibres are burst open, and thus lose much of their felting power, at the same time being rendered very free. Free stuff parts with the water very easily, and thus much of the sizing is lost on the machine, while the weakness, consequent on the treatment of the fibres in the engine, is also a great drawback to making a firm, strong-sized sheet.

To get the best results in sizing stuff prepared in light engines, the roll must be very carefully put down, or the very life will be knocked out of the fibres, and the stuff will froth and "bell" on the wire, in addition to being poorly sized.

Until within the last few years potash alum was almost exclusively used in the sizing of superior papers, owing to the difficulty in obtaining sulphate of alumina from which free acid and iron impurities had been completely separated.

Crystal alum consists of a double sulphate of alumina and potassium, united together with 24 parts of water, as the following formula will show:—

$$Al_2(SO_4)_3 \; K_2SO_4 + 24 \; H_2O.$$

It contains only about 10·5 per cent. of sulphate of alumina, and is thus much more expensive than the sulphates of alumina.

Sulphate of alumina is not a chemical compound of a definite composition, as the alumina varies between 2 and 3 per cent., though that purchased

from reliable makers generally contains 15 or 16 per cent.

Owing to the improved methods of manufacture now adopted, the aluminium sulphates can be prepared in such a way as only to contain the slightest trace of free acid and iron; indeed, in some of the best grades no trace can be found. Notwithstanding this, the crystal form is generally employed for the very best qualities.

Sulphate of alumina is much more soluble than crystal alum, which requires 18 parts of water as against 2 parts required to dissolve 1 part of the alumina.

The amount of alum (or alumina) required to decompose the resin soap will depend on the amount of resinate of soda to be acted on. A size which contains a large percentage of free resin, already precipitated by the degree of dilution to which it has been reduced, will require less than one in which the percentage of sodium resinate is greater.

To ascertain the exact amount necessary to decompose the size, about 50 *c.c.* should be placed in a glass flask, and the number of *c.c.* of alum necessary to convert all the resinate of soda into resinate of alumina run in from a graduated burette.

In this way the correct proportions for the solutions employed in each particular mill can be arrived at. Most paper-makers add to the pulp a larger proportion of alum than is required to form the size coating.

This excess has the effect of hardening the paper

and giving to it a better rattle, and also acts as a mordant, in helping to fix the colour.

If the water used in the mill contains magnesium or lime salts, or, in other words, is hard, a much larger quantity of alum will have to be employed to obtain a well-sized paper.

When size is added to an engine furnished with hard water, it is decomposed as a flaky precipitate, owing to the action of the sulphates of lime and magnesia in forming resinate of lime and resinate of magnesia when brought into contact with the resinate of soda. If, however, sufficient alum be added to precipitate the lime and magnesium salts, before the addition of the size, this decomposition can be prevented, and the resinate of alumina formed as usual.

The best plan is to add the size after the alum used to neutralise the lime and magnesium salts has been thoroughly mixed, and then to run in the amount required to combine with the resin. It is said that, in this way, the precipitate formed by the action of the alum on the salts, which are the cause of the hardness of the water, is not so liable to be decomposed by the excess of alum used, as the presence of the size prevents it from remaining in contact with the pulp in the free state, owing to the ease with which the resinate of alumina is formed.

The exact amount necessary to precipitate the salts contained in the water can easily be determined by treating a small quantity of it with a solution of the

alum used. The number of c.c. required to give a precipitate can be seen from the markings on the burette, and thus the amount required for the gallons contained in the engine is simply a matter of proportion.

Though the water supply, under ordinary circumstances, may be sufficiently free from impurities, a sudden flood may change the channel and lay bare lime and magnesium compounds which, when carried into solution, will have a deleterious effect on the sizing. When the water contains carbonic acid the danger of this is much increased, as the acid dissolves the lime as a carbonate, identical with the carbonate of lime formed by the action of the carbonic acid of the air in the lime left on the fibres by the bleaching solution.

The extent to which the decomposition of the alum may be carried, owing to the presence of these salts, either in the water or in the pulp, will be easily seen from a glance at the following equation :—

$$\begin{array}{c} Al_2 + K_2\,4\,SO_4 + 24\,H_2O + 2\,CaCO_3 \\ 54 + 78 + 128 + 256 + 80 + 24 + 96 = \\ 948 \quad + \quad 200 \\ 2\,CaSO_4 + Al_2O_3 + K_2SO_4 + 2\,CO_2 + SO_3 + 24\,H_2O. \end{array}$$

It will thus be seen that should the water in the engine contain 1 lb. of carbonate of lime in solution, almost 5 lbs. of potash alum will be decomposed, and thus rendered ineffective for sizing purposes.

A consideration of the above facts will show that,

in order to size paper effectively and economically, the greatest vigilance must be exercised to see that the solutions used are kept as near as possible to the proportions which practical experiments, in each mill, have shown to be necessary.

The contact with the heated cylinders on the machine, and the degree of heat to which the paper is subjected, have a great deal to do with rendering the size coating effective. This is probably due to the resinate of alumina, which has been precipitated on the fibres in the engine, becoming fused, and spread out, over, and into the interstices of the paper in such a way as to greatly increase the water-resisting power.

That the sizing of paper, dried by the contact with the machine cylinders, is much better than a similar paper dried by hot air, may be tested by taking a piece from the web after it has passed the second press rolls, but before coming into contact with the heated cylinders, and drying it in a hot atmosphere. A piece should be taken from near the same place in the web, but after having been thoroughly dried by passing over the cylinders, and when the first sample is perfectly dry, the relative water-resisting power can easily be determined.

Wetting with the tongue will show that the paper dried by hot air, without any contact with a heated body, is very poorly sized compared with the piece which passed over the cylinders. An accurate idea of the relative sizing can be obtained by placing a drop

of a dilute alcoholic solution, coloured with a little carnation in order to render the effect more noticeable, on each of the samples, and observing the time which it takes to penetrate to the other side in each case.

The initial cost of the hides and piths used in animal size-making, as well as the expense in preparation and application, has led to investigations with a view to finding a substitute which, while being less expensive to begin with, can be applied with satisfactory results to the pulp in the beating engine, thus doing away with the necessity for the expensive drying plant. The substance which has as yet shown the best results as a substitute for animal size is milk caseine.

Caseine is the name given to that portion of milk which contains albumen. This albumen is analogous to that obtained from eggs and blood, and when a paper is coated with it it becomes capable of resisting the penetrating action of water just as a gelatine-sized paper does. When dry, milk caseine takes the form of a slightly yellow powder, which dissolves somewhat sparingly in water.

The caseine for sizing is generally dissolved in a very dilute solution of ammonia, and in this state may be added to the pulp in the engine. When used in this way, however, there is a considerable loss owing to the finest of the albuminates precipitated by the alum passing away with the back-water on the machine.

Dr. Muth, a strong advocate of caseine sizing, prepares the ammonium albumen, as the caseine is

generally termed, with a solution of ordinary resin size prior to adding it to the pulp; and in this way he claims that the finest albuminates are fixed by the size, and thus prevented from being carried away with the machine back-water.

For fine papers, Dr. Muth recommends the use of 4 to 5 parts of caseine to 1½ parts of resin, and 3½ parts of sulphate of alumina to precipitate. These proportions can be changed according to the quality of the papers to be sized.

Among the advantages claimed for milk sizing may be mentioned the greater elasticity of the fibres when compared with resin-sized papers—an increased yield owing to the precipitated albuminates being retained among the fibres. It is also claimed that, owing to the fatty substances present in the caseine, frothing on the machine is much reduced, and a larger percentage of loading carried with less injury to the tear, owing to the union of the caseine with the loading materials. This union is said to entirely prevent dusting when cutting and printing.

Caseine may also be used for surface sizing, and when dried at a temperature of 266° Fahr. is said to become quite insoluble. When adding to the engine it should be allowed to become thoroughly mixed with the pulp before the alum, which must always be present in excess, is run into it.

Though it can be readily understood that the gelatinous precipitate formed on the fibres will resist the

action of water much better than the resinate of alumina resulting from the resin size, it is difficult to understand how the coating thus formed will possess the same resisting power as that from the thick, strong gelatine which composes good animal size. In mills possessing no facilities for surface sizing, it might be used with advantage for the sizing of a better class of papers than the usual engine-sized qualities.

CHAPTER IX.

THE FOURDRINIER MACHINE AND ITS MANAGEMENT.

In most mills considerable difficulty is experienced, in preventing the emptying of the beaters from disturbing the weight on the machine. As the beaters are usually filled to the lip, there is no room to allow of the water being sufficiently mixed with the pulp before drawing the valve; and the result is that the thick stuff reaches the chests, and, in spite of the motion of the agitator, sinks to the bottom and is drawn into the pipe supplying the stuff cock-box before the water can be got down.

When making a large, heavy sheet, a difference of 5 or 6 lbs. in the ream may be caused by this thick stuff before the water can equalise it. Several devices have been tried in order to do away with this as much as possible. One of these consists in placing a metal float in a small box through which the stuff is led after it leaves the stuff-cock.

The float is connected with a water-cock in such a

way that when it rises, owing to the thickening of the stuff, the water is turned on, and continues to run until the pulp has been reduced by it to the usual thickness, when the float sinks down, and closes the cock.

In some mills a small chest capable of holding about 100 lbs. of pulp, and fitted with an agitator, is used as a stuff-cock box, but with no great advantage; and when working out, the difference in pressure as the level of the stuff becomes lowered causes light weight, in spite of the attention of the machine-man in gradually putting up the stuff-cock.

The best plan, though not always the most convenient, is to place a chest, capable of holding the contents of the beater when diluted with water to the usual consistency, in such a position that it can empty into either of the machine chests. When the pulp and water have been thoroughly mixed, it can thus be allowed to flow into whichever chest it is desired to fill, and being always of the same thickness, the weight is not disturbed.

When no such plan is adopted, the chests should be connected by a pipe fitted with a valve, so that either can be shut off when working out or changing, and the engines should be emptied into the chest, the cock of which is shut, and which communicates with the one out of which the pump is drawing the supply of stuff for the machine by means of the connection pipe. In this way the thick stuff has time to become

more diluted before it finds its way through the connecting pipe to the chest supplying the machine.

If the chests are of iron, the inside should be covered with a coating of cement or some other non-corrosive substance. Chests coated in this way will keep clean longer, and when dirty be much easier washed, than if they were not coated. If the agitators revolve too slowly, a great deal of trouble will arise from bad weight, especially when making thick papers carrying a large percentage of loading.

Agitators that revolve too quickly are, however, very apt to churn grass stuff into soft knots, which are with difficulty broken up by the strainer. A good speed for all round work is six or seven revolutions in the minute. When the stock used consists of rags, the speed may be quickened to eight or nine revolutions without doing any injury.

It is most essential that the stuff pump be capable of pumping sufficient stuff to give a good overflow when the machine is working at its full breadth and speed, as a poor stuff pump is a great hindrance to the turning out of a good weight. To ensure that an ordinary pump will work easily, without any undue straining or jarring, the pipe from the chests should not be less than four inches in diameter.

A new form of stuff pump, which has lately been introduced, works without the rubbers, which are such a nuisance in the older forms. The bottom ball works into the pipe, while the top one works into a cavity in

the barrel, and against an iron saucer fitted to the top of the cover. The balls may be of metal; but if so, they are apt to check the stuff and cause white chips to appear when making blue papers, so that rubber ones give most satisfaction.

When the felts used to cover the sand-trap are nailed down, they should be carried up the sides also, so that no stuff may get in below, otherwise the stuff and dirt which will accumulate underneath will come away at times and cause much broke. If they are simply held down by leads, which is the better plan, a spare set should always be kept, so that they may be washed thoroughly and be ready to put down when the trap is washed out.

It seems to be a fixed idea with the majority of paper-makers that, in order to get clean paper with a revolving strainer, it must be worked with the plates covered. It is very doubtful, however, if much or even any advantage is gained by this method of working, as the strain on the bellows is much harder, and, the suction being stronger, the dirt is more liable to be drawn through the slits than would be the case if the strainer were drawing a little air and thus working more easily.

It is often remarked, in recommending this or that special style of strainer, that it can take through a larger amount of stuff in the hour than any other. Those who talk in this way seem to forget that the first requirement in a strainer is to keep back dirt,

and not merely to force through a large amount of stuff. A strainer which takes through a more than usually large amount of stuff in an hour will be almost certain to draw through a more than proportionally large amount of dirt, especially if the increased power be due to extra suction.

It cannot escape notice that, when the flat strainers, which work by suction, fill up and get no air, a much larger amount of dirt will come through than when they are drawing air. The better plan would seem to be to work two strainers at an easy suction, rather than force dirt and stuff through one by shutting out the air and taxing the bellows to the uttermost.

For straining fine stuff the plates should be of as narrow a cut as will take through the stuff without undue strain. The better qualities of writing papers are, as a rule, made from very fine stuff, and, consequently, will work easily through $2\frac{1}{2}$ or 3 cut plates, but for banks and loans cut 4 or $4\frac{1}{2}$ is necessary, while the long stuff prepared for cartridge papers should be strained through cut 5 or $5\frac{1}{2}$.

It is a mistake to work fine cut plates for long stuff, as the rubbing necessary carries more dirt and knots into the sheet than would get through if wider plates were used. Whatever may be the width of the plates, the greatest care should always be paid to having them fit properly down on the frame. If the plates fit badly, dirt and knots will get through in spite of all the care

given to the choice of the width of the cut, and the same applies to badly-fitting bolts.

It often happens that when the original bolts become used up or lost the new ones supplied are a little longer, and do not fit up to the head; or they may be a little smaller, through the holes having become worn and apt to become slack with the working of the bellows, especially if the plates be worked covered. If the bolts are too long the head will exert no pressure on the plate to keep it down on the frame, and, consequently, the stuff which works down the thread of the bolt will find its way under the plate and into the paper unstrained, and in all likelihood it will have become rolled into a small, hard knot in its passage down the thread. The same thing will occur if any of the bolts work slack, or if the plates do not fit close up to the frame.

The knots which are caused by these defects are easily recognisable, as they are hard and rounded, and, unlike the knots which are in the stuff, they are raised up on the surface of the sheet. When the packing of the strainer ends has become worn, the knots made by the working of the stuff between the vat and the journal of the strainer are not so round, but more feathery shaped.

It sometimes happens that long grass stuff becomes churned into soft knots in the chests, and these, especially if the plates are worn wide, are very liable to pass through the slits unbroken and appear in the

sheet. If such stuff, instead of being run straight from the stuff cock into the sand trap, is led into the box which receives the water from the save-all, and drawn with the water through the pumps, a very large proportion of the knots will be broken up by contact with the sides of the pumps and pressure in passing the rubbers.

If this arrangement is not a suitable one, another plan is to blow a jet of steam against the stuff in its passage to the strainer. This should never be done if it can possibly be dispensed with, as the steam heats the stuff and renders it very free, and, in addition, takes much of the firmness and rattle from the finished paper.

If as much as possible of the backwater be run off, and spring water used to make up what is needed, the weakening action will be much lessened, as the cold water will counteract the heating which is the cause of the softening. Even when the amount of steam used is small, the backwater soon becomes heated by coming into contact with it so often.

Though the small strainer often used as a breast-box does catch strings and blotches, yet if it runs more than twelve hours without cleaning, the blotches which will break away from it will cause a considerable amount of broke.

This is especially the case when calenders are attached to the machine, as the blotches adhere to the rolls, and, in addition to the broke thus made, a

great deal of extra labour is entailed in keeping them clean. A box small enough to secure a sufficient agitation by the rush of the stuff, and at the same time give a steady head of stuff behind the slice, will be found most suitable and will take up less space. For a machine on which there is much changing, and, indeed, for any machine, Holloway's patent deckles and knees are the best.

With the older forms, even though the change may be merely an inch or two, the tacks have to be taken out and the apron rolled up when putting in the deckles, and *vice versâ* when drawing out. On thick papers a great deal of trouble is often caused by the small knots or rolls of stuff which are formed when the apron refuses to lie properly. These rolls are often carried in by the action of the shake, and with difficulty removed with the cutting.

These older forms have this advantage, that when making blues there is no white streak on the edge, such as is caused when the stuff works under the leather of the patent knees. When the amount of broke made when changing from a narrow to a broad deckle, or *vice versâ*, is taken into account, the gain in cutting on blue papers seems somewhat insignificant.

Should the apron have been rolled up for any length of time it often refuses to lie flat; a hand-bowl or two of hot water will soften it, and make it lie quite evenly on to the wire. A thick strip of felt soaked in water

should always be laid along the edge when it has to stand dry for any length of time. The movable knees should be kept up an inch or so, that the apron may lie close into the deckle strap, and so make a good edge.

By pressing down the knee against the strap it can be pushed out a little, and thus a little more cutting room may be gained. To make a good edge with the patent knees, the rubber pads must be fitted so as to come close up to the leather, and lie down on the apron in such a way as to prevent any stuff leaking out.

The apron should extend just as far under the deckle pulley as is possible without coming in contact with the strap, should it have to be lowered a little with the deckle frame through the leather having become worn. The leather should fit easily, so that it may rise and fall with the motion of the tube-roll, and yet keep close enough down to prevent stuff getting under it, while not pressing so hard as to cause knots.

In order to keep them working in this smooth way they should be taken out, and slides cleaned and rubbed with a little oil whenever the knees are off. Care must, however, be taken that all the surplus oil is washed off, otherwise it may get on the strap, and cause it to grip the pulleys hard, through preventing it from carrying enough water to make it slide over them easily.

The level of stuff behind the slice must not be too high, or it will lap over the strap, and, working between the leather and strap, cause small knots to pass down on the edge. While the apron should lie slightly up to the wire, it must not be raised too much, or the depth of stuff as it leaves the breast-box will be apt to cause currents that will spoil the spread. Neglect of this, trivial as it appears, is often the reason why on some machines the spread gives so much more trouble than on others. The movable slice, by which the spread is regulated, must be worked to suit the different natures of the stuff. When the stuff is fine and carrying the water well, the slice should be kept well down, and this is especially necessary when making wove papers. To make a nice close wove sheet, the stuff must be prepared very fine and not soft. No more water should be worked than is necessary to close the sheet, and just sufficient shake to felt it evenly, while the first pump should be well closed.

The effect of such working is especially noticeable on blue and yellow woves, as keeping the pump shut as much as possible, and working the water smoothly up with a gentle shake, has the effect of closing a blue sheet very nicely without drawing the colour from the underside; while the yellow has a clear close look, without the crushed appearance so often seen when much water is worked.

For such papers in the ordinary weights the speed

should not exceed 70 to 75 feet a minute. When making laid more water will have to be put on, the slices raised a turn or so, the shake put up, and the pump opened. If the slice is not raised when much more water is put on, the depth of stuff behind it causes such a rush that the stuff is carried a good way towards the pump before it comes under the influence of the shake, and as the shake is most powerful just at the slices, it can less afford to be lost. If the laid dandy begins to "lift," there is too much water in front of it, and to cure it the pump must be opened, and more water and shake put on, if necessary, to close the sheet.

Bringing up the water by means of the shake, and opening the pump a little, will generally have the effect of curing it. When the stuff is free it rushes out from beneath the slices very violently, and does not settle down quickly. Before settling down, such stuff rolls over on itself, just like a wave, after it has passed the slices, and the more free it becomes the farther will it travel before turning over and settling down.

A careful look at very free stuff on the wire will show that, even when close to the pump, the finest of the fibres are still in a state of agitation. In addition to causing a rush, the slices when worked very low down catch the ultimate fibres, and, turning them on end, cause the sheet to have a broken unfelted appearance. This is more noticeable when

working long stuff, and is the cause of the wavy, streaked appearance of thick coloured sheets. The thicker the sheet, the more shake is required to felt it, and when making thick cartridge or envelope papers, for which the stuff has been kept long, the slices will also have to be raised, so that enough water may be worked to assist in closing the long fibres.

When long stuff is free, it will not stand much shaking, as the edges are apt to be thinned, owing to the ease with which the stuff is lashed back by coming in contact with the deckle straps. To remedy this the shake should be put back, more water put on, and the slices raised.

It is sometimes necessary, owing to the bad construction of the breast-box or apron-board, to stick pieces of paper on the slices, so as to check the rush at some places, before an equal spread can be obtained. This has the same effect on the portion of the sheet which comes under it as having the slices too low.

It often happens, that after working out or being shut down for some time, the stuff, from being milled so long, will be too soft. Such stuff is the most difficult of all to work, as it lies so dead on the wire that it requires water and an energetic shake to spread it, while it parts with the water so badly that it is seldom enough can be put on to make a good sheet.

When stuff is both fine and soft, the paper will have a crushed appearance, especially if working a wove dandy, and will be very likely to stick to the press-roll. In such a case the shake should be put back as much as possible, consistent with closing the sheet, the first pump opened under the same restrictions, and the air-cock on the second pump-box shut, so as to suck the paper as dry as possible.

The guard-board should be put down, so as to prevent the passage of any water, and the weights on the couch-roll increased. This has the effect of drying the paper still further, and making it less likely to adhere to the press-roll. The press-roll should be put down as lightly as possible, and the wet felt tightened up so as to open the warp, and allow the water to be pressed out more readily.

Pouring a little turpentine on the coucher or press-roll has the effect of taking away such greasiness for a minute or two, and enabling the web to be taken off the press-roll without any difficulty. When once down, and under the tension of the draw to the second press, or cylinder, the liability to stick again is not so great, so that by the use of a little of this grease-destroying agent much broke may be saved.

Considerable difference of opinion exists among paper-makers as to which is the most suitable length for the machine wire. The writer has had experience in making paper with 32 feet, 38 feet, 40 feet, and

45 feet wires, and, from a careful study of the behaviour of the different kinds of stuff on each, is of the opinion that for making the best qualities, where look is of the first importance, the best results will be obtained from a 38 to 45 feet wire.

To get a passable sheet on a 45 or 50 ft. wire the stuff must be very free, otherwise it will be so inert before it reaches the dandy that the papers will have a dull, crushed look, especially when making woves. When the stuff is free enough to counteract this deadness, the number of tube-rolls in contact with the wire take away so much of the water that it is often difficult to obtain a clear impression with the dandy, though more water be put on.

The water, leaving the paper thus, can be much reduced in quantity if a number of the tube-rolls are lowered out of contact. In this way the advantage of a longer time under the influence of the shake is gained, while the amount of water leaving the stuff can be regulated by putting up or letting down the tube-rolls. It should also be borne in mind that the greater the amount of backwater, the less likely is the paper to be sized and loaded up to the expectations formed, from the amount of these materials added in the engine.

The speed at which the machine is to be driven, and the nature of the stock to be worked, must always be taken into consideration in regard to the length of wire to be put in. For the proper working

of soft greasy stuff at a quick speed, a 50 ft. wire will be an advantage, in giving more time to get the water taken out; while for fine stuff, not too soft, worked at a moderate speed, a wire 40 ft. in length will be best suited. The speed must also determine the amount of pitch to be given to the wire.

A 40 ft. wire, travelling up to 100 ft. a minute, will require a pitch of about ¾ of an inch from the breast roll to the first guide-roll, while if driven at a speed of 200 ft. a minute a 1¼ inch pitch will be necessary. It is the custom with some engineers to put in very heavy breast-rolls, though for what purpose it is difficult to see.

In addition to the inconvenience of handling a heavy breast-roll, when putting on a wire, the strain on the wire to keep it turning is very great, and tends to wear it out much sooner. A light roll would answer the purpose equally well, and offer much less resistance to the wire when running, as well as being much easier to shake.

The manner in which the shake is given and the length of the stroke have a great deal to do with the spread and look of the sheet. If the stroke is too long the stuff will be washed back from the deckle strap, thinning the edges, and causing a white mark, similar to that caused by a ridge, to appear about 3 inches from the edge on each side.

Should the brasses which support the shake bars become worn, or the pins which connect the bars with

the frame be too thin, the double shake, caused by the play of the brasses or pins, will counteract the original shake, and, instead of the smooth push and pull, a jerky disconnected motion, which will be sure to thin the edges, will be given.

The end of the save-all should not come quite up to the breast-roll, but should be so placed as to ensure that no stuff may become jammed between it and the roll. When too close, any stuff which may pass round the roll will, instead of passing on to the felt-covered guard-stick and being washed away by the water, lie against it and the roll until it becomes hard, when it will act as a serious drag on it when turning. A strong flow of water should always be kept on the guard-stick, which, while being close enough to catch the stuff, should not press too hard on the roll.

Machines which work strong greasy stuff are sometimes fitted with three pump boxes, so that no difficulty may be experienced in taking out the water. The majority, however, have only two, and when the stuff is greasy a great deal of trouble and broke is often caused by the water flooding over the boxes and "worming" in front of the coucher.

This is more liable to happen when the bars on the pump-box are faced with mahogany than if vulcanite, brass, or glass has been used to face them. Mahogany-faced boxes, though less hard on the wire, are very apt to vibrate when drawing hard, and this prevents

the air-cock from being shut as much as is needful to enable the pumps to draw the water out.

A strip of vulcanite inserted between two layers of mahogany along the ends and sides of the pump box does away with the vibration to a great extent, but it must be fitted very closely, otherwise it will draw air.

By working a jacket on the under couch-roll the paper will be less rough on the underside than if it is worked bare, and it will also bulk better. Being less dry, however, the paper is much more apt to stick to the press-roll.

Another objection, and perhaps the most serious of all, is that the small particles of sand or grit, liable to get into the cover, ridge and score the wire very badly, and if the wire is run bare for any time it is very bad for running into a crease. It will be noticed that when a wire, after running some time, becomes slack on either of the edges, it is generally the backside if the water for the wash-roll enters at the foreside, and *vice versâ* if it enters from the back.

The reason of this is that the small holes in the water pipe are apt to become choked up at the end farthest from the inflow, and the wire, owing to being much more dry, is strained in its passage over the rolls. Apart from this, a good strong shower should always be kept on the wash-roll, in order that any free acid left in the pulp and liable to become deposited in the meshes may be washed out.

Attention to this, and also to thoroughly washing the wire when shutting down for any length of time, will keep the meshes clear, lessen the strain of the pumps, and improve the appearance of the sheet, in addition to prolonging the life of the wire.

When making soft sized papers, the froth is usually much more troublesome than when alum has been added to the pulp. This froth often comes away with the stuff from under the slices, and makes "worms." To cure this, the slices must either be lowered a little or more water put on, so that the level behind the slices may be raised and prevent the froth escaping.

Care must be taken not to lower them too much, or the rush of stuff underneath will cause the carbonic acid, always more or less liable to be present in the water used in the beaters, to escape, and in doing so to cause "bells," which, when broken by the dandy, leave a mark on the surface of the paper. This frothing and belling is always worse when steam is used to clear knots in the pulp, and should any of the bleaching solution used in the engine remain undecomposed, the heat will have the effect of liberating the carbonic acid, which is the cause of the froth.

Sometimes, even when the slices are kept clear of froth, small bubbles will escape on the edge and come down the wire with the deckle strap. These bubbles are often the unsuspected cause of worming at the dandy, especially should the edge be a little thickened and the pump-box end not full out. Under

these conditions they are not broken by the suction of the pump, and passing along the front of the dandy cause the worms to come away.

If drawing out the deckle strap a little and also the end of the pump does not cure the trouble, a piece of soft paper should be folded so as to fit in behind the slices close to the knee and along it a little, so as to prevent the bubbles escaping along the edge of the strap.

The bells which gather on the edge of a laid dandy can be kept away by rubbing a little oil on the dandy just off from the edge of the paper, or, better still, by moistening the cloth used to keep away spots just over the edge with a little sperm oil, which has the same effect.

The trouble with froth is so bad in some mills that patent froth-killers are resorted to in order to keep it down. These concoctions are very often adulterated with resin, which adulteration is sometimes carried to an extent that causes the paper to stick determinedly to the press-roll, and leaves a deposit of resin among the stuff which gathers on the doctor.

When the liability to froth is great, special attention should be given to the water used in the engine, as the carbonic acid expelled from the lime salts contained in hard water is often one of the sources of its origin.

The alum solution should be added when furnishing, and if the water be hard an additional quantity of

alum will require to be put in in order to precipitate the salts contained in it.

The chlorine compounds must be completely neutralised by means of antichlor.

The following recipe is said to make a very efficient froth-killer, the use of which will lead to no bad results in causing the paper to stick to the press-roll:—One-and-a-half gallons of linseed oil, mixed with one gallon of bleach, and a gill and a-half of turpentine.

To keep the dandy free from bells when making laid papers at a quick speed, a gentle puff of steam should be blown through it from a perforated iron pipe hung down in front of it in such a way that the steam will meet the dandy at a slight angle and be blown clear of the stuff.

For quick drying, the stuff must be quickly prepared in the beater, so that it may not be soft, but settle down quickly and part with the water easily. Though the engines must not be made too stiff to prepare such stuff, there is no reason why they should be filled thinner than usual.

Stuff prepared in an engine filled about the usual consistency, but not heavily, when treated somewhat sharply with the roll at first, and yet not so cut up as to be rendered fine, will felt closely and part with he water easily though made at a quick speed.

When, however, the engines are filled with a larger proportion of water than usual, lightly loaded (with

stuff, not clay, or other so-called "loading" material) and cut up quickly, the stuff produced will undoubtedly be free, and most likely fine, at least the finest of the fibres will be very fine, owing to the ease with which they are got at by the roll, with the result that it will "bell," froth, and stick to the press-roll.

It would seem as if such stuff when once up the press-roll had not enough cohesiveness to stand drawing down, but when once down lacks the power to run up so often as might be expected, from the difficulty experienced in getting it down when it does break; as it will be noticed that with stuff thus prepared there are fewer breaks at the press-roll than is sometimes the case with stuff which leaves the roll much more easily.

It sometimes happens when making wove papers, with the pump well shut, that the drawing power of the pump is hampered owing to the cock being so much closed, and when this is the case the back lash from the pump causes the paper, especially if it be thin, to fold over at the edge in an almost imperceptible crease. This crease may give no sign of its presence until the last set of cylinders, or calenders, are reached, but it is almost certain to cause a break there. A little more water, or shake, and the pump box opened a little, will make this disappear entirely.

Another very frequent source of cracks and breaks between the cylinders and calenders is having the wire too slack. When the wire is too slack it is apt to

crease the paper when passing under the couch-roll, but in such a way that it is scarcely noticeable, unless the machine-man knows where to look for it.

This is most liable to happen when making thick paper with a narrow deckle; and the first thing the machine-man should do, when he is at a loss to account for breaking on such papers, is to hold a light under the web, between the under-coucher and the wet-felt roll, so that he may make sure if the creases are there. If the wire is causing them, they will seem like a small black streak running a little way in from the edge. Tightening up the wire a few turns, and putting more weight on the coucher, will have the effect of curing them.

When the coucher cover becomes worn on the edges much trouble and worry are often caused by the paper, instead of couching properly, adhering to the jacket, and, if not running up the roll altogether, going far enough up to cause the edge to crack and the web to crease going under the press-roll.

This may be greatly helped by easing the weights on the coucher and raising the guard-board a little. The guard-board must not be lifted much, just enough to keep the cover moistened with water, so that the suction on the paper may be lessened. Slackening the wire draw will also help it, by allowing the web to go farther down the wire, and thus the risk of its adhering to the coucher is not so great. By fixing a small jet of water so that it will play on the edge

of the coucher, which comes in contact with the paper just before it passes under the guard-board, the edge can be kept much cleaner, which also lessens the liability of the web to adhere to it.

Dandy rolls are usually made half an inch less in circumference and three-quarters of an inch more in breadth between each name, to ensure that the sheet will cut to the size after the shrinkage and expansion caused when the paper is in contact with the hot cylinders and on the driers. Sometimes dandy rolls are wanted to cut above their given size, as when, for instance, a sheet 17 × 27 in. is to be made with the foolscap roll which cuts 13¼ × 16½ in. In order to bring the name up to the size it will have to be stretched half an inch.

With long stuff, which stretches easily, this is, under ordinary circumstances, a matter of no great difficulty; but when fine stuff is being worked it is sometimes quite impossible to obtain the size without unduly stretching the sheet. The first thing to be done in order to bring up the size, in such a case, is to hang the dandy as much as possible, and so make it revolve more slowly; then the cloth should be let down on the roll, as much as can be risked without retarding it in such a way as to cause it to streak the paper.

The wire should be lowered so as to tighten the web between the under-coucher and the wet-felt. The second press should be driven a little harder by taking off a piece of the packing from the driven pulley, or,

if there be none on, by putting a small piece on the driver, and the draw from the second press to the cylinders tightened up in the same manner.

It is better always to take off, than put on packing, unless the belts are very slack and inclined to slip, as in this way there is less chance of the packing accumulating and stretching the belts, besides causing the draws to work with an irregular jerky motion, which is very likely to crack the web at some time when they are tighter than usual. Even when the size is up to the measurement, without any undue straining of the web, the distance between the names must be measured frequently, especially if the nature of the stuff is being altered.

A fine engine will draw in the sheet as much as one-eighth, and sometimes three-sixteenths, of an inch, while longer stuff will cause it to expand in the same proportion. Not infrequently, when working a broad deckle, the distance between the middle names, measuring across the wire, will be found to be less than that between those in the side sheets, though the usual three-quarters of an inch has been allowed when putting the names on the dandy.

This is especially liable to occur on a broad machine, and is due to the couch-roll and press-roll yielding in the middle when put down hard at the edges. The middle sheets are thus damper when they come in contact with the hot cylinders, and the suddenness of the reaction makes them shrink more than the side

sheets, which are much drier and less affected by the heat. The patent anti-deflection press-rolls, with which some of the most recently built machines are fitted, are said to completely prevent this unequal pressure.

Dandies for loft-dried papers should have one-eighth more than the usual three-quarters of an inch allowed between the names, owing to the shrinkage while hanging in the drying loft. Dandies for grass papers should not have more than half to five-eighths of an inch allowed, as grass shrinks less than rags.

When setting a lined dandy it must be placed perfectly parallel, so that the lines come exactly on the top of each other when the sheets are folded. To ensure that it is parallel it should be measured, after having been placed in the brackets, either from the couch-roll or the deckle straps on each side. The simplest way in which to determine whether a named laid dandy is placed so as to have the names equidistant from the edges is to count the number of bars from the centre of each name to the deckle edge on each side.

The same holds good when the water-mark consists of a name and a device on each sheet. Should the name extend over an odd number of spaces, such as five or seven, while the device occupies an even number, such as four, the space between the middle bar of the name will require to be taken as the centre, while the centre of the device will consist of the middle bar,

When setting a named wove dandy, the water-marks of which are placed as on a laid roll, namely, across instead of round the roll, as is usual with the wove dandy, the breadth of the names will have to be measured, and, from the points thus fixed as centres, the breadth outwards to the deckle edge on each side made to agree. Named wove dandies on which the water-marks are placed round, instead of across, should be measured in the same way.

When the names are placed so that one side of the sheet will be blank, while the water-mark occupies the other, a piece of the web, the full breadth, should be taken off whenever the paper has reached the reel, and after allowing for pairing it should be marked off with a pencil, according to the size of the sheet.

When this has been done it should be again divided into half or quarter sheets, and then a glance at the sheet held against the light will show if the names are right, and if not, in what direction they will require to be altered. A few years ago Brown's patent laid dandy, which possesses several advantages over the ordinary laid roll, was introduced.

This dandy may be described as a wove roll round which the laid lines are fixed, while the bars, instead of running round, as is the case with the ordinary form, are placed along its length. One advantage in using this roll is that on 60-in. machines large and medium post can be made three times 16½ in. and

17½ in. respectively, instead of twice 20¾ in. and 22¼ in., as is the case with the common laid roll.

When large orders of these sizes are made a considerable increase in the output can thus be effected. It is well known that less colour is required to give the same shade on wove papers than on laid, the reason being that the close pressure of the wove dandy brings the finest of the fibres to the surface; and thus, by making the surface smoother and more compact, the colour is much better brought out. Owing to the close wove cover underlying the laid lines on Brown's dandy, the same even pressure is given to the surface, with the result that less colour is necessary, and in addition the sheet is much clearer.

In the making of high-coloured papers, for which 20 or 30 lbs. of expensive colouring matters require to be used, this saving is not to be underrated. Though a large amount of water is used with it, it will not "lift"; at least the tendency is so small that it may be said not to exist, as it is only when there is an excessive amount of water before it that it shows any signs of lifting.

Another great advantage is that it does not "bell" when driving hard. It has, however, one very serious drawback by reason of which its adoption has been much restricted. Owing to its weight, as at present made, the laid lines are very liable to leave their impression on the under side, making it rough.

In order to avoid this it must be hung on the

brackets as much as possible, and a large amount of water brought forward. If, instead of the ordinary form of wove roll, the improved skeleton form were used to support the laid lines, the roll when finished would be much lighter, and thus the danger of the impression showing on the underside would be much lessened.

To prevent "blowing," the felt-roll immediately in front of the press-roll should be raised a few inches above the level of the under press-roll. When making thin papers, the resistance of the air between the web and the felt often causes blowing, even when the draw between the wire and the felt is as tight as it can be run without cracking the edges. In such a case the press-roll must be put hard down, the wet felt tightened up, so that the warp may be opened out and allow the air to escape and the seam kept square.

When the seam of the felt is off the square the warp lies at the same angle as the seam, and thus by closing the pores retards the escape of the air. A very simple and effectual remedy is to run the paper over a small tube-roll, placed just in front of the press-roll about an inch above the wet-felt. If the edges are uneven the frayed stuff adheres to this roll, and has to be taken off frequently, or it will crack and stretch the edge of the web.

Another plan is to run a small felt-covered tube-roll on the top of the paper as it passes on to the first felt-roll; but when making named papers the name is

liable to become stretched unequally owing to the irregular speed of this roll. By placing a small pump-box, connected with the vacuum pumps, under the wet-felt close up to the under press-roll, the suction of the pumps will draw all the air through the felt, and thus completely cure blowing. Putting on the felt with the pile lying the wrong way will also tend to keep it away, owing to the pores being kept more open, thus allowing the air to escape more readily.

When running a broad deckle the wet-felt should be kept tight, as in this way the edges are opened and allow the water to be better pressed out, and thus there is less danger of the web sticking to the press-roll. To square the seam either of wet or dry felts, the side that is first must be tightened up. The same rule applies to the wire, and in each case care must be taken to check the run, as both wires and felts will incline to run from the side which has been tightened up.

There is great diversity of opinion among machine-men as to which side a dry-felt will run to when tightened up. Some hold that it will run to the slack side; others that it will run to the tight side. The direction in which a dry-felt will run depends on which side of the cylinder it has been tightened up.

To take the instance of a single cylinder felt supported, say, on five rolls. Should the top roll be tightened up at one side the felt will invariably run to the other, and if the seam was straight before tightening it will forge ahead at the slack side,

Suppose that the foreside top roll has been tightened up in order to square the seam, which has gone so much ahead in front as to threaten to run the felt into a crease, and that the felt is travelling back so quickly as to be in danger of turning over and bursting at the backside edge; though the guide-roll has been changed as much as possible to bring it forward, raising the backside top roll would set it forward again, but would not put away the crease, which is the greatest trouble.

If, however, the foreside roll, round which the felt turns as it leaves the cylinder to go up over the top roll, be lowered about a quarter of an inch or more if need be, the seam will at once begin to come square, and the felt will come forward, thus running to the tight side.

Should the roll round which the felt runs to come in contact with the cylinder be lowered, the felt will run to the backside, thus proving that a dry-felt will run to the tight side when tightened at the side at which it leaves the cylinder, and to the slack side when tightened at the side at which it comes in contact with it.

The seam should always be squared up after starting, and carefully watched so that it may not run ahead at either side; otherwise the felt will become unequally stretched, and give much trouble by moving about when it gets old and worn out.

The rubbers with which most press-rolls are now fitted are a great boon in saving the felt from being

out, should any hard substance pass between the rolls when the press is firm down. No oil should ever be poured down the screw, as it would tend to rot the rubber; and besides, there is no need for doing so, as the oil on the bottom side is quite sufficient to keep it working smoothly, as from time to time it passes through the nut which works against the rubber when the roll is raised for turning or putting on a wet-felt.

When couching and pressing lightly it sometimes happens that the pile on the wet-felt becomes clogged up with the soft stuff, and the paper adhering to it until just under the second press goes up in a crease. A narrow piece of wood—a long foot-rule by preference—placed between the paper and the felt just as it leaves the press-roll, will, by separating the paper from the felt, prevent the creasing caused in this way. The foot-rule should be fixed on to the frame in such a way as to be clear of the felt, otherwise it will gather wet stuff which, passing round on the felt, may cause a break at the press-roll.

It is the practice in some mills to press very lightly with the first press and keep the second press hard down, the idea being to have as little felt marking on the underside as possible, and also by taking out the wire mark with the pressure applied to the underside, to improve the surface.

With this method of working the second press felts have to be frequently changed, owing to the passage of so much water pressed from the paper clogging

them quickly. A dirty second press felt is one of the most frequent causes of the unevenness in drying, termed "cockling," as the paper in contact with the dirty part of the felt is much more damp when it comes in contact with the cylinders, and thus is liable to become blistered from the suddenness of the drying.

Keeping the dry-felts tight has the effect of preventing cockling by pressing the paper more uniformly against the cylinders. Whether there be any special need to have the paper flat or not, the drying should always be conducted gradually, the heat of the cylinders gradually increasing as the paper nears the dry end. With thin papers, especially those made from strong linen rags, the press must be put hard down, and the heat of the cylinders so regulated as to leave the paper slightly damp when it comes in contact with the last two or three, which should only be sufficiently hot to dry without causing any sudden contraction of the web.

Unless the seam of the second press felt be perfectly square it is very liable to crease; if it should do so the side which is last should be lowered down, as by doing so the creasing is counteracted more quickly than by tightening the side which has run ahead. When passing the second press the draw from the first press to the cylinders must be slackened, and to do so double the amount of packing that would be necessary to slacken the same strain from the second press to the cylinders will be required.

The same rule holds good when passing the smoothing rolls, and of course double the amount has to be taken off when putting the paper through again. Though, as a rule, when changing from thick to thin papers the draws will require to be tightened up, very little packing will be necessary should the speed be much faster than that at which the thicker paper was made. This is due to the increased momentum given to the pulleys owing to the quickened speed.

When making thick paper at a speed of about 18 ft. per minute, the belts will require to be very tight, or they will slip, owing to the strain of driving, unaided by the momentum which a higher speed will give. It sometimes happens that when driving at a slow speed the wire will run to one side, and refuse to respond to the guide. Should this threaten to damage the wire, the speed should be quickened up, as by so doing the wire will answer the guide much better.

If the machine be fitted with the improved cone driving, quickening the speed is a very simple matter; but should the difference thus made be insufficient, as much as 20 ft. more per minute can be obtained by tightening up the thumb-screw attached to the governor of the engine.

This increase of the speed generally has the effect of bringing the wire back, but should it prove ineffectual the only plan left is to shut down, and, having taken off the couch-roll and slackened the wire a little, to draw it back into its right position.

It is assumed that everything has been already done, so far as altering and tightening the wire at the side to which it is running can be made to effect any change in its course. When making webs, such as those for use in the Morse telegraph machine, difficulty is often experienced in getting them to bulk equally. This unequal bulk may be caused by a want of uniformity in the spread on the wire, or a difference in the pressure of the couch or press-rolls. Badly ground calender rolls will also cause inequality both of surface and of bulk.

In this connection it should be remembered that, when paper is passing through the calender rolls, the drier it leaves the press-roll the better will it bulk. Should the pressure on the rolls be very light, or should the paper be finished rough, the less pressure put on the press-roll the bulk will be better.

Each machine has, owing to differences in fitting up or other causes which exert an influence on the pressure given to the paper, its own peculiarities. Sometimes a softness on the edge may be filled up by hanging or putting down the second press-roll, according as the paper is being glazed or not. When the stuff is free, and thus spreading and filling up the edges well, the webs will be found to bulk more uniformly.

Should the paper begin to break between the calender rolls from any unaccountable cause, the first thing the machine-man ought to do, after having

satisfied himself that it is not too dry, is to see that none of the draws are too tight, especially the draw from the first to the second press-rolls. Should this draw be too tight, the web will be pulled and stretched at the edges, and though no cracks may be visible, the contraction, and consequent strain, as the paper is dried, will cause the weakened edge to break as the draws become tightened towards the dry end.

Should the draws be all right and the breaking continue, the edges should be closely watched for a [illegible]n of the wire, to see that no dirt has become fixed in the meshes, and by hindering the passage of the water and the suction of the pumps is causing a weak spot near the edge of the web. A dirty or raised seam will cause breaking both at the press-roll and the calenders. A little vitriol poured on the dirty part will generally clean it; but should the dirt still remain, blowing it with a jet of steam will take it out.

Not unfrequently dirty spots, more than usually difficult to get rid of, will be noticed in the wire after the mechanics or joiners have been fitting up new boxes about the machine. These are generally caused by small pieces of white lead, which have been left lying about the boxes, coming away with the stuff and being pressed into the meshes by the couch-roll.

When the trouble is caused by a raised seam, the "stent"-roll should be put down a few turns. The wet-felt should next be examined, to see that no dried stuff or other hard substance has adhered to it near

the edge of the web. Should any such hard material be coming between the paper and the felt as it passes under the press-roll, cracks, only perceptible as small dark marks, will be made. If this is the cause of breaking, the marks will be noticed by examining the end of the web just where it has been severed.

Breaking at the calenders may also be caused through having the draws too slack, thus causing the paper to fold over at the edge when entering the press-rolls. Should the cylinder draws be too slack, especially near the wet end, the felts, if they are tight, will take up the slack, and in doing so cause very minute folds on the edge, which, through being damp when calendered, will make a weak spot on the edge of the web.

When making thin papers at a quick speed, the press-roll should be kept well down, while the steam on the first cylinders should be regulated so as to dry very gradually. By keeping the press-roll firmly down, the paper is made more dry, and thus more easily handled when leading it over the machine.

When starting very heavy papers, at a slow speed, the small plug just behind the apron-board should be drawn out, so that the flooding, so liable when starting such papers, may be prevented. Sometimes it is necessary to change from one revolving strainer to another without shutting, and the strainer to be started is generally furnished from the chest by means of pails.

PREFACE.

THE Author is well aware that the subject of PRACTICAL PAPER-MAKING is one to which a much larger and fuller work than the present might have been devoted. He trusts, however, that this little volume, slight as is the treatment of most portions of the subject, will in some measure supply a need which he has himself felt for several years, and more especially during the first years of his apprenticeship—namely, the need of a work on Paper-making which, while not neglecting those teachings of theoretical and practical chemistry, the understanding of which is necessary for the successful and economic production of paper, should at the same time give due consideration to the practical working of the Paper Mill.

He is aware, also, that to carry out this plan, even on the unambitious scale of the present work, there

is required of an author intimate knowledge of the actual working of the mill, such as can only be obtained by years of practical work in the various departments. His own experience, he is able to say, having been such as should qualify him for the task he has here undertaken, he ventures to hope that many Paper-makers and Millowners will find in these pages knowledge and information of no little value, which has not hitherto been accessible in a similar form. To what extent the work answers his desires, his readers will be best able to judge.

Special attention may be invited to the illustrations of the Microscopical Examination of Paper and Paper-making Materials, which have been reproduced from micro-photographs.

In the APPENDIX will be found some useful Tables, Data, etc., compiled from various sources.

BLACKBURN, PENICUIK.
March 1894.

NOTE TO SECOND EDITION.

FOR the present edition, the work has been carefully revised and some additions made (enlarging the volume by about 18 or 20 pages), so as to bring the information fully up to date.

SANDFORD-ON-THAMES, *near* OXFORD.
November 1906.

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of the loft must be kept as near that of the ordinary summer atmosphere as possible, and as much advantage as possible should be taken of the atmospheric air, when sufficiently dry to be admitted to the loft without risk of making the papers mussy after drying.

CHAPTER XI.

GLAZING AND BURNISHING.

When paper is glazed by the calenders attached to the machine, it is usually damped before being put through the calender rolls. Prior to this, however, it has generally passed between what are called the smoothing rolls, which are situated just before the last set of drying cylinders. These usually consist of two rolls heated by steam, though not to the same extent as the calender rolls.

By keeping the paper a little damp as it passes through these smoothing-rolls, and not heating the last cylinders any more than is necessary to prevent damp spots, the surface imparted by the calender-rolls is much improved. When a good surface is wanted the stuff must be kept fine, as long stuff, though taking on a good finish, always rises up in the sheet, causing a roughness, especially on the underside. To quote the remark of a shrewd old paper-maker—"It's just like smoothing sand and smoothing gravel."

Even papers made from long stuff are very liable to lose their surface, owing to this rising of the longer

fibres, unless the pressure in glazing is sufficient to thoroughly close the sheet. The improvement which can be effected on the surface by finer stuff is greater than is usually supposed.

The author knew a machine-man who used regularly to get his beater-man to empty a finer engine as soon as possible after his shift came on, with the result that, when the foreman came round, in about an hour and a half, to inspect the surface, the paper then being made was very much higher in finish than that made just before the outgoing shift had dropped off work.

The form of damper usually employed to moisten the paper before it enters the calenders consists of two hollow copper drums of about 15 or 16 inches diameter, though, of course, they may be of any desired size. These drums are filled with cold water, and kept cold by means of a continuous flow passing through them.

A copper pipe, perforated with numerous very minute holes, is placed along the front of each of the drums, so that the steam which is blown from the holes will condense in the cold drums. The drums are so placed that when the paper is running over them one will come in contact with the top and the other with the under side of the paper. The moisture deposited on the drums by the condensation of the steam is thus carried away on the paper, and helps greatly to improve the surface when subjected to the pressure and heat of the calender-rolls.

Owing, however, to the moisture thus applied being merely on the surface, and not having time to penetrate into the paper, the high finish thus obtained is very liable to go back. A little sperm oil should be poured on the drums just at the edges of the web, so that the water may be prevented from passing on to the calender rolls, and so causing rust on the edges.

Printing papers, on which a very high finish is wanted, are often glazed on the super-calender, after having been given a good machine finish. The contact with the alternating metal and cotton, or paper-covered rolls, has the effect of imparting a velvety feel, unobtainable by the passage through the machine calenders.

A little of an alkaline soap, made by dissolving white soap in caustic lye, is often added to the pulp in the engine, in order to improve the surface.

When paper is damped before glazing on the super-calender, the rolls must be worked at a heat sufficient to dry it. The cooler the paper to be damped is made the greater will be the amount of water absorbed, without causing the rolls to "bag" when winding on the damper, and the more pressure will it bear in passing through the rolls. For this reason both tub-sized and engine-sized papers should be allowed to lie in a cool place for some time before damping.

To obtain a surface which will not be liable readily to go back, the pressure must not be too heavy, nor must the rolls be worked with too much heat. It is

much better for the appearance of the paper to put it through twice than to work heavy pressure, and glaze with one passage only. The amount of pressure which can be applied without unduly crushing the paper depends very much on the stock from which it is made.

Papers largely composed of straw require a good pressure, in order that they may be closed so as to avoid the rising before referred to. This is especially the case when such papers have been damped.

Owing to the hard nature of their ultimate fibres, wood and straw papers are very liable to become wrinkled when damped, and this will be more noticeable if they have been hot when put through the damper. Should papers consisting wholly, or in large proportion, of wood become too dry on the calender rolls, they will be very apt to break, owing to their hard, brittle nature.

In glazing highly-finished paper for magazine and illustrated work, in which the surface and not the appearance is of the first importance, the pressure applied in the super-calender is often such as to cause all the sheave and gritty matters to show up.

In glazing high-coloured papers made from coarse stock which has been kept long in the engine, very heavy pressures are necessary, in order to obtain the degree of finish usually imparted to such papers. Quite a common pressure for that class of papers is about 11 tons on each end of the calender, while some

of the most recently fitted up calenders are supplied with weights equal to 50 tons.

At all times, but especially when glazing tinted papers, the greatest care must be exercised to keep the heat of the rolls as uniform as possible, as carelessness in this respect is very often the unsuspected cause of the appearance of shades. This applies with even greater force to the burnishing calender, as even a slight variation of the heat of the burnishing-roll will cause shades to appear.

A good plan to prevent the overheating of the burnishing-roll is to let both steam and water into it, so that it may be quickly cooled down should the heat become too strong.

In friction glazing, as in super-calendering, the best results can be obtained by working with little or no pressure, and putting the paper through more frequently. To keep the burnisher working smoothly, the wax should be frequently applied, so that it may not dry and crack the paper. Should the paper be too damp when glazing or burnishing, it will be liable to become blackened. This blackening is sometimes attributed to the want of wax on the burnisher, but neglect to put wax on the roll, though a very frequent cause of cracks, will not, under usual conditions of working, be liable to cause it.

The surface imparted to paper glazed in a properly constructed plate calender is much more silky than the finish obtained on the super-calender. This is due to

the pressure on the plate calender being so much less, and thus the original elasticity of the fibres is preserved to a much greater extent.

This has the effect of making plate-glazed papers bulk much better than similar papers finished on the super-calender, and in addition they have a more mellow appearance. Great care must be exercised that the plates used are free from gritty matters, otherwise the papers will be very liable to become indented and rendered rough on the surface.

CHAPTER XII.

CUTTING.—FINISHING.

Cutting.—The first thing to be done when preparing to start a revolving cutter is to place the roll with least breaks—that is, if those to be cut are not free from breaks—in the bottom bracket nearest to the feeding-rolls.

The reason why a roll without breaks should be put there is that any breaks or cracks on the others may be led over the boards and through the rolls without the risk of catching and tearing, being supported on this under web. As this roll is also the guide when setting the circulars, the one put on should be as evenly wound as possible. When this roll has been put on, and before any of the others are lifted into position, the paper should be torn perfectly square, and, after folding, put carefully into the feeding-rolls.

The utmost care is necessary that it may not be slanted, even in the slightest degree, as should it be even an eighth of an inch off the square, the

circulars will be set fully an inch off the line; and if the brackets cannot be altered to bring the sheets right, there is nothing for it but to shut down and put the circulars into line again.

The number of rolls which can be cut at one time depends on the condition of the cross-cutting knife; but even with a sharp knife six rolls of the substance of large post 21 lbs. is a heavy filling.

Should the filling be too heavy, the under sheet is very liable to be torn in a peculiar manner, very difficult to detect, unless the cutter-man knows where to look for it. This tear is usually of a small semi-circular shape, somewhat irregular, however, and as it is on the under sheet it may run for some time before it is noticed. It is torn off just when the cross-cutting knife is passing the dead knife, and falls down on to the carrying-felt.

When this tear makes its appearance, which will be either when the filling is too heavy or the knife too blunt, the best plan is to break off one of the rolls, and thus allow the knife to go through the remaining sheets without any shock.

Great care must be exercised, when setting newly-sharpened circular knives, not to press them against the under knives until the fine wire edge has taken on a skin. To bring up this skin, they should be gently rubbed with a fine file. A good plan is to put a piece of thin copying or tissue paper between the block and the knife when setting for the first

day or two, and as the edge becomes hardened gradually to bring them closer.

When new the cross-cutting knife needs little attention; but the parts not cutting the paper should always be kept well oiled, so that there may be no attrition as they come in contact with the dead knife.

When letting out the spring nearest the front of the cutter, it must be done very cautiously, and after doing so the knife should always be driven through with the hand, to make sure that it is not too far out. Should it be too much sprung it will lock into the dead knife and seriously damage both. Should the cross-cutting knife miss at any point, the portion on each side of it must be rubbed down with a file so as to bring them to the same level as the point which is missing.

The feeding-rolls must always be kept free from oil, especially the jacket, as should any get on to them they will slip over the paper instead of drawing it in regularly, and cause short and long sheets. This may be detected by watching the feed of the paper, as if the rolls are slipping it will be very noticeably irregular. When oil has got on to them a rub with a cloth moistened with turpentine will take it off immediately.

Should the paper be badly cut, it should be closely watched between the tube-rolls and the cross-cutting knife, and, if any lurch is seen then, the screw of

the pulley wheel must be looked to, as, if it has become loose, it will cause the paper to be unevenly cut. The screws of the spur-wheels must also be kept tight, or the cutting will be very defective. Should the cutting be bad, owing to a backlash on any of the pinions, a piece of clean leather inserted between the shaft of the cross-cutting knife and the brass at the back of the cutter, and firmly wedged down by means of the collar, will remedy it. Though it is useless unless the shaft heats a little, care must be taken to keep it moistened with oil to prevent undue heating.

When the length of the sheet being cut is 50 inches and upwards, some difficulty may be experienced in keeping the sheets from rushing against the revolving frame, owing to the slow revolution of the cross-cutting knife compared with the speed of the other portions of the cutter.

To cure this, two of the blade screws should be unscrewed, and a long sheet of paper or clean wrapper screwed between them, opposite to the paper. These sheets are allowed to hang like flags, and as they pass round against the paper serve to drive down the sheets on to the carrying felt.

When cutting a short sheet of perhaps 14 inches, or nearly the length of the fall between the dead knife and the felt, the heaving felt is very liable to come against it just as the cross-cutting knife is going through, and thus both uneven and badly squared

sheets are the result. A piece of thick twine stretched across the cutter, on the top of the paper, an inch or two back from the dead knife, will generally cure this; but it is rather dangerous mending a break on the top roll when it is on, as the cutter-man must lift the string with his fingers, to allow the tail of the paper to pass under. In such a case the better plan is to shut and lead it under, when it can be done with perfect safety.

When cutting friction-glazed paper the feeding-rolls will not take more than three rolls at a time with security, unless the brasses are wedged and firmly pressed down at both ends, when six rolls may be cut at once and nothing go wrong. The high polish on the paper, together with the wax applied at the burnisher, causes the middle sheets to slip so much that they will often be as much as an inch short, while the top and bottom sheets are quite right.

As there is not usually a guard on the rolls, this pressing is not to be recommended, on account of the danger when mending breaks. Should even a small piece of broke run round the under feeding-roll, the size of the sheet being cut will be instantly raised, though no harm will result should any run round the top roll.

Should the circular or block knife, running out of gearing between those which are cutting, be left slack, either the one or the other will be sure to slide along the shaft until they nearly meet, making a long straight

line on the paper, which, though not easy to detect, neither plate calenders nor anything else will take out again.

When the circulars are dull, and the machine cutting friction-glazed or even ordinary papers with a narrow selvage, the knives at the edges will cut the sheets very unevenly, which will soon be noticed, as sheets cut in this way are generally about a quarter of an inch broader than the size.

The best cure for this is to shut and drive a nail into the board between the feeding-rolls and the knives, and opposite each circular, which is cutting the bad edge, to hang a folded sheet (not more than two plies) on to the nail, and then lead it over and underneath the board, so that when the cutter is started it will run into each circular and hang there, being clasped on the nail.

Should a break on the top roll run over instead of between the tube-rolls, when cutting square paper, the sheets are liable to be cut off the square, though when cutting angle little or no difference is caused. The belt which runs over the expanding pulley should always be kept tight, as should it be left slack the sheet will rise in size from 1 inch to 4 inches. In fact, from the drags which hang on the rolls, upwards, everything must be kept tight in order to ensure regular cutting.

If the feeding-rolls are creasing the paper, the edge where the crease runs out should be eased slightly in order to put the crease away. Should this be in-

effectual, easing the tube-rolls will slacken the strain and also help to put the creases away, but when altering the tube-rolls care must be taken that the square is not altered. Tissue and copying papers are most liable to crease, and sometimes the top tube-roll has to be taken out altogether in order to prevent creasing, though, usually, lifting it about one turn of the screw at each side will be sufficient.

To prevent creasing at the feeding-rolls the top one should be lifted, after all the tails are in, and the size measured ready for a start, and a long strip of soft felt about two inches broad wound round each end and made to adhere by means of resin, so that it may not come off, but press on the paper above the selvage which the end circulars are taking off. Enough felt should be put on to admit of the jacket being raised about one-sixteenth of an inch above the paper.

The cutter should not be allowed to run longer than two or three minutes without paper if the knives are in gearing, because, should they become heated by friction, they are very difficult to put right again. For the same reason care must be taken that no part of the knife outside the breadth of the paper is left hard pressed.

Should the knife be blunt and any part of it pressed hard up by means of the springs in order to make it cut, the square is very liable to be altered, and while the back sheet may be all right the front one will sometimes be half an inch off the square. This is most

liable to occur when the centre springs are pressed up, and may be remedied by inserting five or six plies of wrapper underneath the metal plate at the back of the dead knife. This wrapper may either be put in at the front or the back, according to whether the square is off the one way or the other, and the thickness of the plies can be regulated so as to give the distance that the sheet requires.

The number of inches which the carriage requires to be moved when altering the draw depends on the angle or dip at which the frame is built. When finding the square the sheets must always be taken from the felt in the one direction and folded in the same way, that it may be readily ascertained whether they are over or under, should they require altering.

When changing from the single to the double draw, the square, though quite right when running the single sheet, will, owing to the slow revolution of the cross-cutting knife, be found to be under the size, the variation depending on the length of the draw. Should the draw have been lengthened the carriage will require to be drawn out a little, and when changing back to the single draw it will have to be put in again.

In cutting angles the brackets should be drawn as near to the front of the cutter as possible, so that the backside sheet will have a shorter distance to travel over the boards; and care must always be taken when making, that the papers are not too broad for the cutter, as, if so, the points of the sheets will run straight into

the frame instead of down the felt. The second tube rolls, worked when cutting angles which come up to about forty-five degrees, and sometimes over that, must always be perfectly square, or they will draw in the paper unevenly.

When the tube-rolls are not drawing quick enough to keep the paper tight, a turn or so of paper wound round them will draw it up quite tight. When this paper is put on it should be kept about an inch clear of each edge, otherwise the rolls are very apt to knock small holes or cracks into the sheets.

If the feeding-rolls have been pressed for burnished paper, the blocks must be taken out before cutting papers such as cartridges, which are usually finished rough, as the hard-pressed jacket would put a glaze on that portion which passed under it. The string across the dead knife should never be used when the draw is fifty inches or upwards, as the slow motion of the knife sends the paper over it, and thus makes it dangerous for the square.

When starting a new knife on the English cutter, care should be taken to see that it will go through without becoming locked; and with new or newly-ground circulars the same precautions should be employed as mentioned in connection with the revolving cutter.

Should the feeding-rolls slip, and thus draw the paper unequally, a piece of thin paper wound round the top roll will make them draw much better. While

the "dancer" must not be allowed to fall too far down, the paper must not be drawn so tightly as to raise it against the platform, or it will be sure to cause a break.

When quickening the speed of the drum by means of the screw attached to the arm, in order to bring up the name, the belt should be put up the cone a little in order to bring up the draw from the reel, and thus prevent the "dancer" becoming too much drawn up.

When the cross-cutting knife misses it should be raised up a little by means of the screw; this should be done very carefully, in order to avoid the risk of bringing it too far up, and thus causing it to grip the dead knife.

When cutting lined paper it may happen that the lines do not come exactly parallel when the sheets are folded, owing to the dandy not having been set perfectly parallel on the machine.

This may be remedied to a great extent by winding thin strips of paper round the "dancer" at the side where the lines are farthest ahead. This has the effect of drawing the side to which it is put so much back as to bring up the side which is farthest off the parallel.

Finishing.—The different stages through which the paper passes in the salle are entirely dependent on the qualities produced in the mill, and thus the degree

of overhauling to which it is subjected varies with the requirements of each different mill. As a rule, the higher the quality and price of a paper the more closely is it overhauled, and, consequently, the greater is the proportion of retree laid out.

During the last year or two the engine-sized machine-finished papers have reached to such a degree of perfection that it would almost seem as if eventually the better qualities of tub-sized papers would be driven out of the market altogether; and, consequently, the engine-sized papers have to be much more closely overhauled than was thought necessary several years ago.

Plate V.

FIG. 9.—CHEMICAL WOOD AND ESPARTO × 150.

CHAPTER XIII.

MICROSCOPICAL EXAMINATION OF PAPER.

NOTWITHSTANDING what has been written about the reagents necessary to enable the microscopist to distinguish the various fibres after they have been made into paper, they are of little practical use. The reason of this lies in the fact that the groups into which the fibres can be separated by means of these reagents are those which are most easily distinguished without their use.

The reagent most commonly used is a solution of iodine in potassium iodide. Cotton, flax, and hemp fibres, when moistened with this reagent, are coloured a dull red violet; esparto, straw, and chemical wood fibres are nearly colourless, excepting the brownish-yellow tinge of the solution. Unbleached, or imperfectly bleached, wood and jute show this yellow tinge; but, owing to the presence of the incrusting substances, it is much more distinct.

In order to render the colours more distinct, a dilute solution of sulphuric acid may be used to moisten the

fibres, after they have been in contact with the iodine for some time. For the student of paper-making, who merely wishes to become acquainted with the physical characteristics of the various fibres, and thus be able to determine the materials of which the papers which may come under his notice are composed, a very good beginning may be made with a microscope provided with optics magnifying from 80 to 100 times.

The glass slides and covers used in mounting can be had from any chemical dealer, and cost very little; while the teasing needles can easily be made by inserting the thick end of an ordinary needle in a small piece of wood, or the handle of a crochet needle, and bending the point to the desired angle, after having heated it in the gas.

A small bottle of glycerine, for softening and rendering the fibres more transparent, should also be procured, and a pair of small forceps will be required, in order to lift on and off the glass covers.

Before beginning to examine paper, specimens of the different fibres, after they have been reduced to half-stuff, but before treatment in the beater, should be mounted, so as to be ready to hand for comparison. Suppose the first of these specimens to be prepared is that of esparto grass, a small piece of which has been obtained from the *presse-pâte* web. As the ultimate fibres are not firmly felted together, they yield very readily when drawn apart by the needles.

A small piece should be placed on the slide to be

used, and having been covered with a drop of glycerine, should be separated into ultimate fibres by means of the teasing needles. It is much better to examine three or four isolated fibres than a complicated network, as by doing so the characteristic structural details, together with the length and the formation of the ends, can be much better seen.

Papers to be examined should first be boiled for a few minutes in a dilute alcoholic solution, in order to remove the size coating from the fibres. Even when aided by reliable specimens, the work of distinguishing the various fibres is at first attended with difficulties which can only be overcome by much practice.

By using dilute colouring solutions of carnation or magenta when mounting, the characteristic appearance of the upper skin is more distinctly brought out. When working with a low power objective, the field is enlarged, and thus the whole length of the fibres brought into view, with the result that a much better idea of the comparative proportions of the different fibres is obtained. For this reason, the objective employed for ordinary work should not exceed 100 to 150 diameters.

The advantage of becoming thoroughly accustomed to view the fibres under such a magnification will be much appreciated when a higher power is substituted, in order to render the structural details of any fibre, or group of fibres, more apparent. When changing the objectives from a low to a high power, the proportions

must always be borne in mind, as fibres which present a similarity of appearance, though differing as to length and diameter, are, at first sight, apt to be confounded.

For instance, esparto, especially Spanish, may sometimes be mistaken for linen, as seen under the lower power, owing to its enlarged appearance. If it is possible to obtain a little of the pulp just after furnishing, and before the roll has had time to reduce it, and, again, as it is ready to pass over the machine, a very good idea of the effect of the treatment can be obtained.

The quickest way to mount such a sample is to dilute it with water until it is thin enough to be viewed by transmitted light, and then pour a little into a small glass live box, when it is immediately ready to be examined. Viewed in this way, the fibres are much less transparent, owing to the absence of the glycerine, and thus the appearance of the external parts is much easier noticed. Examined in this way, cotton fibres will be seen to be quite opaque, while the transparent central canal of linen fibres will be very apparent.

Cotton fibres consist of opaque, flattened, ribbon-like tubes, frequently twisted upon themselves. The side walls are thin, while the central canal is large. The outer skin is rough and granulated, presenting, when dry, a dark, opaque appearance. When moistened with glycerine or Canada balsam it loses this dulness and becomes transparent. On examining the fibres before beating, one end will be seen to taper away at

Plate VI.

FIG. 10.- LINEN, COTTON, AND ESPARTO × 130.

FIG. 12.—MANILLA AND COTTON × 120

a slight angle to a fine point, while the other takes the form of an irregularly flattened knob.

Linen fibres are long and, like cotton, tubular; but the side walls are much thicker and firmer, while the central canal, though smaller, is easily distinguished by its transparency, even when no glycerine has been used in mounting. They are smaller in diameter than cotton fibres. Sometimes linen fibres, notched like a bamboo-cane, are met with, though usually the side walls are smooth and regular. (See Plate VI., Fig. 11.)

Hemp fibres are somewhat like cotton in that they are flattened in the same way and have a large diameter; but they are not twisted upon themselves in the manner characteristic of cotton fibres. (See Plate I., *Frontispiece*, Fig. 2.)

Manilla fibres have a larger diameter than hemp, and the side walls are well defined, making the central canal, which is large, very easily seen. The side walls are more uniform than those of the cotton fibres, and present a more lustrous appearance when mounted in glycerine. (See Plate VI., Fig. 12.)

Jute fibres have unequally thickened side walls, which, however, are smooth externally. The fibres are very seldom completely free from incrusting matters, which, when dry, obscure the central canal.

Wood fibres, especially those from pulp prepared by the sulphite methods, are transparent. They resemble cotton fibres in their flattened, ribbon-like appearance,

but can easily be distinguished from them by their stiff, rigid, wooden-like form. Not infrequently, wood fibres, twisted upon themselves like cotton, are met with. They are long and of large diameter, while those from the pine woods show numerous small vessels or dots. When dry the upper skin is rough and granulated in appearance; and this is especially noticeable in "sulphate" pulp. When mounted in glycerine they become very transparent, and it is only by carefully gauging the focus that the characteristic dots can be brought into view. (See Plate V., Fig. 9.)

Esparto fibres consist of short, smooth tubes with finely tapered ends. The central canal, though small, owing to the thickness of the walls, is quite apparent. Esparto can easily be detected, though present in a small proportion, in a paper, owing to the characteristic serrated cuticular cells which are so easily recognised. (See Plate V., Fig. 9.)

The ultimate fibres of straw, though similar in appearance to esparto, are smaller both in length and diameter, and the ends are more pointed. The rigidity and smoothness of the side walls are very apparent. The cuticular cells vary in form with the different kinds of straw from which the pulp has been prepared.

Straw pulp also contains small oval-shaped cells, which are derived from the soft, pulpy matter of the stem, and, when seen, are a sure indication of the presence of straw. While most of the fibres are smooth and regular, sometimes they will be seen to

present a peculiarly jointed appearance, which serves to distinguish them from the smaller esparto fibres.

The fibres of mechanical wood present a short tangled appearance, and are bound together, by means of the incrusting substances, into small bundles. The presence of these incrusting matters causes them to be dark and opaque; and it is for this reason that mechanical wood is used to prevent the transparency imparted to papers made from highly bleached sulphite pulp. (See Plate III., Fig. 6.)

The presence of mechanical wood in a paper may be detected by means of a solution consisting of equal parts of sulphuric and nitric acids, a few drops of which will produce brown stains on paper containing mechanical wood. A solution of aniline sulphate forms a very good reagent for the detection of mechanical wood, owing to the deep yellow stain which it produces on paper containing it.

Though the difficulties in the way of making a quantitative examination of paper are great, yet to the paper-maker who has already become expert in distinguishing the various fibres in the finished paper, such an examination is quite within the range of possibility, providing that he can obtain samples, the authentic composition of which is known, from which to prepare standard specimens.

The first and chief difficulty lies in the obtaining of such samples; but should he have access to the beating department of the mill, he can, as the result of some

little attention and practical knowledge, obtain samples, the percentage composition of which is accurate enough for all practical purposes.

A very convenient way of preserving these samples is to fill a number of small glass-stoppered bottles, with the different samples, the percentage composition of which is known, taken from the machine breast-box, or better, as it settles down between the first and second slice.

When it is desired to mount such stuff, a small drop of it should be lifted out by means of a glass tube drawn out to a fine point. Before doing so, however, care must be taken to shake the bottle vigorously, in order that the portion examined may represent the true composition of the whole.

After the drop has been placed on the slide, the excess of water should be removed before putting on the glass cover, in order that the fibres may not be carried out of the field when the cover is pressed down. This may be accomplished by carefully sucking it up by means of a slip of good blotting-paper cut to a fine point, care being taken that none of the fibres are disturbed, or made to adhere to the blotting-paper when so doing.

A very good plan is to place two specimens of the stuff, or paper, on the same slide, mounting the one in glycerine or dilute alcohol, without the addition of a colouring agent, while the other is coloured with a dilute solution of carnation. If preferred, a drop of

Plate VII.

FIG. 13.—COTTON AND PEARL HARDENING × 125.

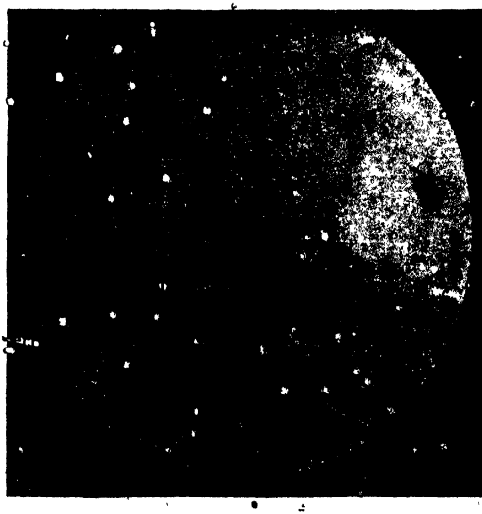

FIG. 14.—CHINA CLAY × 122.

[To face page 171.

stuff may be mounted alongside a piece of the finished paper, when it will at once be seen whether the action of the shake, or the contraction on the drying cylinders, has had any effect in altering the distribution of the fibres.

As the knowledge of the composition of the papers examined depends for its accuracy on the results obtained by comparison with the standard samples, it is obvious that, in order to obtain satisfactory results, no care must be spared in order to insure that the standard preparations may be trustworthy.

When it is considered that the composition of a paper may, through the addition of even a small quantity of "broke," reduced by the edge-runner, or, it may be, furnished to the potcher with the grass, become very complicated, the difficulty of obtaining trustworthy samples will be understood.

The degree of fineness to which the fibres have been reduced in the beater must also be taken into consideration, as the ultimate fibres of rags and wood are, owing to the length, more liable to become cut up under the action of the roll than those of esparto and straw. The presence of fibres added as "broke" is much more easily recognised in papers made from long stuff, owing to the greater degree of fineness to which they have become reduced, consequent upon their having been in contact with the rolls and plates so much oftener.

Viewed microscopically, the various forms of load-

ing are seen to be possessed of features sufficiently characteristic to make their detection a matter of no great difficulty, especially after the microscopist has gained a knowledge of these characteristics. The finely-divided particles of which barium sulphate is composed are seen to differ from those of china clay, in that they are mostly wedge-shaped, while the clay particles are irregularly rounded in form.

Pearl hardening is composed of minute needle-shaped crystals, the peculiar form of which makes them easily recognisable. (See Plate VII., Figs. 13 and 14, and Plate VIII., Figs. 15 and 16.)

Plate VIII.

FIG. 15.—PEARL HARDENING × 129.

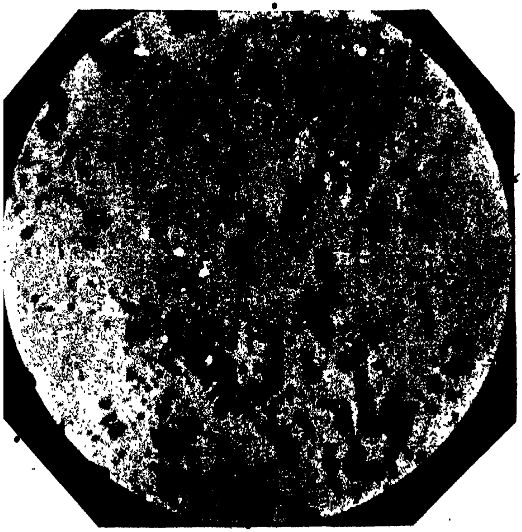

FIG. 16.—TERRA ALBA × 135.

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CHAPTER XIV.

TESTS FOR INGREDIENTS OF PAPER.

Animal Size.—The presence of animal size in a paper can be detected by means of the reaction with tannic acid. A piece of the paper to be tested is torn into small fragments and placed in a test-tube. A small quantity of distilled water is then poured in, and the tube held over the gas for some time in order that the boiling may extract the gelatine, and at the same time concentrate the solution, so that the reaction may be the more easily noticeable.

When it is considered that the size has been extracted the boiling should be stopped, and after cooling the tannic acid should be added. If animal size is present a flocculent milky precipitate will at once be formed, owing to the tannate of gelatine produced by the combination of the gelatine with the tannic acid.

The consistency of the precipitate depends on the amount of animal size present, papers sized with a strong solution of gelatine yielding a thick gelatinous

precipitate; while, should the sizing be weak, a thin milky precipitate will result.

When the reaction is so weak as to be scarcely discernible, Millon's reagent will require to be employed. This reagent is prepared by dissolving a known weight of quicksilver in an equal weight of fuming nitric acid, and after cooling adding an equal volume of distilled water.

When paper containing animal size is moistened with this solution and brought to a gentle heat over the gas flame, a red colour will be produced. This colour will vary in intensity according as the sizing of the paper has been strong or the reverse.

Alum.—To test paper for free sulphate of alumina half a sheet should be torn into small pieces and boiled in hot water until it is reduced to a pulpy state, when the contents of the small flask in which the boiling has been conducted should be poured on to a filter, and the pulpy mass well washed.

The filtrate should next be boiled for a few minutes with a small quantity of ammonium chloride solution, together with a slight excess of ammonia, when any sulphate of alumina present will be precipitated as a finely divided white precipitate.

Starch.—Starch can be detected by means of the characteristic blue colour produced when a drop of iodine is placed on a paper to which starch has been

added. Before the amount of starch present in a paper can be ascertained, the size coating must first be removed. This is accomplished by boiling the sample to be tested in a strong alcoholic solution, acidulated with a few drops of hydrochloric acid, until the resin has gone into solution.

The paper is then washed with alcohol, dried, and weighed. It is next boiled with a more dilute alcoholic solution, also acidulated with hydrochloric acid, until all the starch has been dissolved out. The point when this is accomplished is determined by means of a dilute solution of iodine, with which the paper is moistened from time to time, until the characteristic blue colour ceases to be produced.

After washing and drying, the weight is again determined, when the difference in the two weighings will give the amount of starch present.

Chlorides.—Should it be suspected that any of the chlorides, resulting from the decomposition of the bleaching powder solutions, are present in the paper, the simplest method of proving their existence is to precipitate them by means of silver nitrate solution, to which a few drops of pure nitric acid have been added.

To accomplish this the paper to be tested should be boiled with a small quantity of distilled water, and, after filtering, a few drops of the silver solution added to the filtrate. Should chlorides be present a white

curdy precipitate will at once separate out, which, when exposed to the light, will soon become blackened.

Engine Size.—The presence of engine size may be ascertained by heating small pieces of the paper to be tested in a strong alcoholic solution, when the resinate of alumina will be partly decomposed. By adding a considerable excess of cold water the dissolved resin will be precipitated, as it is insoluble in a dilute solution of alcohol.

Schuman's method for the determination of the amount of resin consists in heating the paper in a dilute solution of caustic soda until the resin is dissolved, and after filtering and washing the paper well, adding to the filtrate a sufficient quantity of sulphuric acid to decompose the resin soap. The precipitated resin is then obtained by pouring the milky solution through a weighed filter.

After washing and drying, the filter containing the resin is carefully weighed, and after deducting the weight of the filter, as previously determined, the weight of resin is found.

Mineral Substances.—The amount of mineral matters present in a sample of paper is ascertained by burning a known weight of it in a small platinum crucible, and from the weight of the ash calculating the percentage contained in it.

When pearl hardening is suspected—and it can easily

be detected, owing to the purity of the ash when compared with the dull colour of china clay—the blow-pipe must be used with caution, as it (the ash) is very liable to be fused and blown out of the crucible should it be vigorously fanned.

Owing to the reducing action of the carbon, the ash from pearl hardening will contain a quantity of its weight as calcium sulphite, and should be moistened with sulphuric acid and again burned in order to convert the sulphite back to sulphate.

When calculating the percentage of pearl hardening carried by the pulp, it must be borne in mind that, as the hardening when added to the engine contains 2 atoms of water, 136 parts of the ash are equal to 172 parts of the hardening as furnished with the pulp.

CHAPTER XV.

RECOVERY OF SODA.

Incineration.—At first a matter of compulsion, owing to the pollution caused by running the spent lye from the boilings into the rivers, the incineration and recovery of the soda has, under the conditions of working made possible by the improved forms of roasters now in use, become a source of profit to the paper-maker.

The idea in roasting the spent liquor is to burn up the non-cellulose substances which the soda has dissolved from the raw materials, and which are combined with it.

The Porion roaster, owing to the simplicity of its construction, and the excellent results that can be obtained when it is properly managed, is the one most used in this country. As usually constructed, it consists of an evaporating chamber, in which the lye is concentrated by the heat from the gases on their way to the chimney; a combustion chamber, which serves the double purpose of retaining the

heat and consuming the smoke; a pan in which the incineration is conducted; and a suitable furnace to supply the heat on which the several stages in the recovery depend. With this roaster all liquors from 5° Twaddle can be profitably evaporated.

The lye, as it comes from the boilers, or store tanks, enters the evaporating chamber, which is provided with rapidly revolving fans, or splashers, as they are sometimes termed. These splashers dip into the lye, and, as they revolve, throw it up against the roof of the chamber in a very fine spray, through which the hot fumes from the furnace and pan pass on their way to the chimney. This has the effect of greatly increasing the evaporating surface, and thus liquors entering the chamber at 6° or 7° Twaddle, leave it, on their way to the pan, concentrated to 35° or 40°.

The greater the concentration of the lye on entering the pan, the less water remains to be driven off, and thus the roasting can be accomplished with a smaller consumption of coal.

It is the practice in some mills to draw the charge of soda from the pan once every twelve hours, and where this mode of working is adopted the lye is allowed to run from the evaporating chamber to the pan in a continuous flow for about seven hours, and only shut off about four hours before the time for drawing. During the time that the charge is burning off the soda must be well worked in the pan, so that

it may be perfectly dry, and of a dull red colour when drawn.

It often happens, especially when much rag lye has to be burned, that the liquor becomes much reduced in strength, and taxes the energies of the roaster-men to the uttermost to get the pan ready in time. When this is the case, the damper should be opened more than usual, and good fires kept up. When, however, the liquor is of the usual strength, the damper should be worked as much shut as possible consistent with complete combustion. In this way the temperature of the combustion and evaporating chambers is kept up, and the concentration of the lye much more easily effected.

When burning off, special attention must be paid to having the damper well shut, otherwise a considerable portion of the finest of the soda will be carried into the combustion chamber and on to the chimney.

By regulating the roasting so as to draw three charges in twenty-four hours, a better yield of soda in proportion to the coal consumed can be obtained, as by such a method the burning is conducted more rapidly, the proportion of soda carried away by the draught is much less, and thus the yield is increased. Working in this way, 20 cwts. of completely calcined soda, containing 45 per cent. total alkali, can be obtained with a consumption of 25 cwts. of coal.

The coal used should be as free from sulphur as

possible, as any sulphur present combines with the soda and reduces the yield of caustic in the subsequent causticising process. While the cake, which forms on the lye in the process of roasting, must not be allowed to become hard, it should not be broken up too frequently, or greater difficulty will be experienced in keeping up the heat.

After drawing, the soda should be loosely laid down, in such a way that it may burn out without running together and forming a cake. In about three days it should be turned over, and in about eight or nine days will be ready for the lixiviation tanks. The length of time for which it is allowed to lie generally depends on how soon it is required.

Lixiviation.—The soda-dissolving tanks are generally three or four in number; and, indeed, to conduct the extraction of the soda in a satisfactory way four or five tanks are necessary. The dissolving is conducted in much the same way as the washing of the grass in the steeper tanks. When the soda has been put in it is covered up with water, which has previously been used as a third water.

After the soda has been covered with this weak liquor, pumped from the weak liquor tank or allowed to flow from a charge which has been exhausted and is ready to be cleaned out, clean water, generally heated, though some prefer to use cold, is turned on, which, after passing through one, two, or three tanks, ac-

cording to the number of tanks employed, rises on to the fresh charge, and, passing through it, is run to the store tank as a first liquor.

This extraction may be continued for twenty-four to thirty hours, or even longer, according to the system adopted and the strength of the recovered soda, and the liquor should stand about 72° Twaddle when first run off. This strength will gradually become weaker, until it reaches 22° Twaddle, when it is turned off, and made to run on to a fresh charge, which has been put into the tank, cleaned out in the interval.

After running into this fresh charge for some time it is shut off altogether, and steam turned on to boil it for ten to twelve hours, and the liquor, after allowing sufficient time for settling, run to the weak liquor tank, when the mud is lifted out and the fresh charge furnished to the tank.

Another method of extracting the soda is to cover it with the liquor taken from a third or fourth boiling, and boil it for twelve hours before running off. After running off this strong liquor the tank is again filled up from a charge boiled for the third time, and then boiled for other twelve hours, and the liquor run off to the store tank, where it is mixed with the strong liquor. If the soda is not yet exhausted another liquor may be taken off before allowing the mud to boil for two or three days.

This third liquor may be run to the store tank if considered strong enough, and, if not, used to extract a

fresh charge. When a fourth liquor is taken off it goes to the weak store tank, and is used to cover the fresh charges put in. The strong liquor obtained by this method will stand about 70° Twaddle, the second about 15° Twaddle.

A first and second liquor are run off together every day, and the strength of the lye in the store tank is maintained about 40° Twaddle. In some mills the soda is dissolved in circular iron tanks, divided into two compartments by a perforated iron partition. The recovered soda is placed in one of the divisions, and after being covered up with weak liquor is boiled by means of a steam-pipe which reaches almost to the bottom of the tank. The agitation is further increased by a blast of air drawn in with the steam. The charge is boiled until it is quite exhausted, and then another quantity is put in, the tank being cleaned out once or twice during the week.

After the non-cellulose matters extracted from the plant substances during the boiling, have been burned up in the roaster, the soda, owing to the oxygen and carbon which it has taken up during the calcination, and prior to that, during the boiling, has become converted into sodium carbonate. The action of the water in the lixiviation tanks has simply separated the sodium carbonate from the insoluble impurities; and before the liquor thus obtained can be substituted for the caustic soda bought from the chemical manufacturer, it must be converted from the carbonated to the

caustic state. The following equation shows how that chemical change is effected :—

Carbonate of soda.		Lime water.		Caustic soda.		Carbonate of lime.
Na_2CO_3	+	$CaO + H_2O$	=	$2\ NaOH$	+	$CaCO_3$

$$46 + 12 + 48 + 40 + 16 + 2 + 16 = 46 + 32 + 2 + 40 + 12 + 48$$

$$106 \quad + \quad 56 \quad + \quad 18 \quad = \quad 80 \quad + \quad 100$$

A glance at the figures will show that 56 parts of lime are required to convert 106 parts of carbonate of soda into the caustic state, and that the amount of caustic produced from these quantities does not exceed 80 parts. In actual practice the yield of caustic soda is less than the theoretical quantity, owing to proportions retained in the lime mud.

In some mills this causticising process is conducted in circular tanks, or boilers, fitted with agitators, to ensure the thorough contact of the lime with the liquor to be causticised. The liquor from the lixiviation store tanks is run into the boiler and generally reduced to between 20° and 22° Twaddle. This reduction is rendered necessary owing to the fact that a strong solution of sodium carbonate would react on the caustic first formed, and so retard the operation.

The boiler having been filled to the usual height, the steam is turned on, and the lime put into a small cage fitted to the side of the boiler in such a position that the lime is immersed in the liquor. As the reaction proceeds the lime is gradually taken up by the carbonic acid of the carbonate of soda to form the lime carbonate, left as the sediment in the boiler, while

the soda unites with the oxygen and hydrogen of the water to form caustic soda.

To ascertain when the reaction has been completed, and all the soda present as carbonate converted into caustic, a little of the liquor is lifted out, and, after allowing the lime to settle, is treated with a solution of equal parts of sulphuric acid and water.

If there be any effervescence, due to the escape of carbonic acid still uncombined with the lime, the reaction is not complete. Either the lime added has not been sufficient to combine with all the carbonic acid present in the carbonate of soda, and more must be added, or sufficient time has not been allowed to complete the reaction. Should no effervescence take place on the addition of the testing solution, all the sodium carbonate has been converted into caustic soda.

When the washing water from the boilers is used to bring the liquor to the desired strength, more lime will require to be added in order to combine with the carbonic acid present in the washings; and even then the caustic liquor will be apt to froth on being tested, owing to the presence of uncombined carbonic acid. After the reaction is finished the agitator should be shut out and the lime allowed to settle before the lye is drawn off.

About an hour is required for this; and, after the lye has been run to the tanks from which the supply for the boiler is drawn, the lime mud is again agitated and boiled for about an hour, when the liquor obtained,

after settling, is also run to the store tank. The weak liquor drained from the lime mud should be used to conduct this second extraction, which should stand about 6° to 8° Twaddle.

Should a third liquor be taken off it is better not to boil it, but only to bring it to boiling point, and then shut off the steam; as when boiled for the third time the lime mud becomes pasty, and, in addition to retaining caustic, is difficult to drain.

By running up a boiler with the drainings from the lime, and allowing it to stand for about twelve to fifteen hours, a caustic solution standing about 10° Twaddle can be obtained. Before settling it should be allowed to mix for an hour or so.

In order to oxidise the sulphur compounds, principally the sodium sulphide, which have been formed by the action of the sulphur contained in the coal, a strong current of air is sometimes blown into the boiler during the causticising. In addition to oxidising the sodium sulphide to sulphate, it has the effect of producing a much more thorough agitation of the lime and the soda.

When the causticising vessel consists of the egg-shaped boiler, which is preferred by many paper-makers, the agitation is maintained by means of the steam (and air, when the air-blast is employed) issuing from small holes in an iron pipe laid along the bottom of the boiler. Very much better results are said to be obtained when using this form of boiler.

Though the aluminate and silicate of soda present in the recovered liquor are, to a large extent, decomposed during the causticising process, a considerable amount of soda is retained in combination with these compounds, and thus rendered unavailable.

In causticising liquor obtained from the spent lye in which straw has been boiled the loss arising from this cause is very considerable, owing to the large proportion of silica in combination with the soda. It is claimed that by treating the recovered liquor with bicarbonate of soda, prior to causticising, the aluminate and silicate of soda are decomposed, with the result that practically the whole of the soda held in combibination is set free, while the sodium sulphide is also decomposed.

The soda added as bicarbonate is available, and as much as 11 per cent. of alkali can, it is said, be saved by employing this method. The plan recommended by the advocates of this system is to boil the liquor to which the bicarbonate has been added for a quarter or half an hour before adding the usual amount of lime.

In place of causticising by means of lime, ferric oxide may be used as a causticising agent. This process possesses a distinct advantage over the lime method in that the caustic solution is obtained in a concentrated form direct from the lixiviation tanks.

The rationale of the process consists in the expulsion of the carbonic acid from the recovered ash when fused

with ferric oxide. The sodium ferrate thus formed is decomposed during the lixiviation with the formation of caustic soda solution and ferric oxide, which is thus available to causticise a second charge of soda ash. It will thus be seen that the ferric oxide, owing to this regeneration, is continuously available.

This process, notwithstanding its advantages, is more suited to the needs of the chemical manufacturer than to the requirements of the paper-maker.

Multiple Effects.—During recent years the principle of multiple effects, seen in its simplest form in the evaporator of the Porion type, has been made the basis of several new systems of evaporation. The principle of multiple effects, as applied to evaporation, is dependent on the fact that the boiling point of a liquid is lowered in proportion as the pressure exerted on its surface is diminished.

This is the reason why the temperature required to boil water at the top of a hill is less than that found necessary at the bottom, where the atmospheric pressure exerted on its surface is greater than that to which it is subjected at the greater height.

Under the normal atmospheric pressure of 14·7 lbs. per square inch, the temperature at which water boils is 212° Fahr.; and by lowering the pressure in the chamber in which the evaporation is conducted, by means of a vacuum artificially produced and maintained, a corresponding reduction in the number of

degrees of heat necessary to effect the conversion of the liquid into steam can be effected.

Thus under a vacuum of 5 inches = 12 lbs. per square inch of surface pressure, the temperature at which water will boil is 195° Fahr.; 10 inches vacuum represents 185° Fahr., 15 inches 160° Fahr., and at 20 inches the temperature is reduced to 150° Fahr. The efficiency of the multiple effects evaporator is, however, largely dependent on another peculiarity connected with the boiling of liquids—namely, the utilisation of the latent heat contained in the vapour given off when water is converted into steam.

Each pound of water converted into steam at atmospheric pressure absorbs 1,146 heat units, but about 965 of these units have been absorbed in producing the molecular change from water into steam, and when the steam is again brought into contact with water at a lower temperature, it yields up these latent heat units, with the result that the temperature of the liquid in contact is raised; and if, as in the case of a vacuum evaporator, the surface pressure be lowered in the proper degree, it becomes possible to raise the temperature of the liquid by means of the latent heat to the boiling point required under the lowered pressure, and again utilise the latent heat of the vapour thus produced to raise a further quantity of liquor under a still lower pressure to boiling-point.

In the multiple effects evaporator, the vapour from a liquid boiling under normal pressure is made to boil

a second portion of the liquid, the pressure upon the surface of which has been diminished by means of a vacuum pump. By further reducing the resistance of the pressure of the surrounding atmosphere a third portion of the liquid may be brought to boiling point. Thus it will be seen that the number of effects is dependent on the vacuum which can be obtained in the evaporators.

In the system known as the Yaryan, the spent lyes are made to flow through a system of pipes inclosed in an egg-shaped boiler or shell, into which the steam for conducting the evaporation is led. As the liquor flows through the pipes, it is concentrated by the heat from the steam playing round them; and at the end of each effect it is made to flow into a special chamber, in which the separation of the concentrated lye and the steam produced by the concentration is effected.

On leaving the separator, the liquor and steam are conducted through separate pipes to the next effect; in which the former is, through the agency of the latter, still further concentrated.

In a quadruple-effect evaporator the steam pressure is maintained at 20 lbs. per square inch in the first effect, by means of steam supplied direct from the steam boilers. The steam from the separator of this effect enters the second effect at a pressure of 11 lbs. per square inch, and after effecting the concentration passes on to the third effect at a pressure of 5 lbs. To carry out the concentration with this pressure a

vacuum of 17 in., equal to about $8\frac{1}{2}$ lbs., is maintained.

In the fourth effect the vacuum is further increased to about 24 in. With the apparatus described, lyes entering the first effect at from 8° to 10° Twaddle are concentrated to between 40° and 44° on issuing from the last effect.

Apart altogether from the expense connected with the fitting up and upkeep of such a system as the Yaryan, it is very doubtful if it can hold its own when compared with the evaporator of the Porion type. With the latter, liquors standing from 8° to 10° Twaddle can, under the ordinary conditions of working, be concentrated to 40°.

Another serious drawback connected with the Yaryan is the difficulty experienced in cleaning out the tubes. The deposit which gathers on the inside of the tubes is so extremely hard that it can only be removed by means of long and tedious scraping.

Very good results are said to be obtained from the Chapman and Fawcett multiple effect evaporator, which is somewhat similar in principle to the Yaryan. It is capable of dealing with liquors at from 2° to 4° Twaddle, and of concentrating them to from 44° to 46° with economical results.

In the Gaunt multiple effect evaporator, which is largely used in American mills for the evaporation of soda liquors from wood pulp boiling, the liquors are made to flow over a series of pipes through which the steam is conducted, and the liability to choking up

which is such a drawback to the systems in which the concentrated liquors flow through the pipes, is thus obviated.

The first effect is usually supplied with live steam under pressure, and the steam given off by the liquor in contact with the heated tubes is led to the second effect, and utilised to further concentrate the liquor from which it has been driven off in the first effect.

As in the Yaryan, the number of effects employed depends on the density and volume of the liquors to be dealt with, and the fact that it becomes difficult to maintain a circulation when the liquor reaches the neighbourhood of 40° Fahr.

The Scott Multiple Effect.—In principle, the Scott recovery plant varies little from the other well-known types, quadruple effect being the usual form of installation, although other numbers of effects are installed according to the steam supply available and the volume of liquor to be treated.

The heating surface is arranged in series of 2 in. and 4 in. tubes, a number of 2 in. tubes being placed round each 4 in. tube, so that the latter may draw down from the top of the pan the liquor which has been thrown into it by the 2 in. tubes. The number of 2 in. tubes is generally about fifty to one 4 in. tube, but this varies according to the number of effects.

The result of this arrangement is that the liquor travels so rapidly over the heating surface—while at

the same time keeping the tubes full of liquor—that deposition on the tubes is reduced to a minimum, and they require comparatively little cleaning.

Other things being equal, this freedom from liability to choke up is a very valuable feature, as the cleaning and replacing of choked tubes is a very considerable item in the cost of upkeep of a multiple effect evaporator.

In comparing the results obtained from different forms of evaporators and roasters, the strength and uniformity of the lyes are too often overlooked, and consequently a false opinion of the merits of the systems compared is obtained. For instance, a roaster working when only the first liquors and washings are evaporated will show much better results than could be obtained from the same form of roaster when two washings have to be burned.

Again, when a considerable quantity of rag lye has to be evaporated, especially if it be from the better grades, the amount of coal consumed will be much larger in proportion to the turnout of soda, than would be the case in roasting an equal quantity of lye from esparto or straw.

The Warren Rotary Furnace.—During recent years the introduction of the Warren rotary furnace has made it possible to effect the incineration of the concentrated liquors more expeditiously, and with greater economy, than is possible with the furnace or pan of

the Porion type. Its merits were quickly recognised in American mills, with the result that it has been largely introduced in conjunction with multiple effect evaporators.

The fire-box, which is of the usual type, is so arranged that it can be drawn forwards to allow of easy access to the furnace proper.

The furnace consists of a cast iron casing lined with firebricks, similar to the rotary kilns used in cement manufacture, being conical in shape, with the larger end towards the fire-box. The rotary movement is obtained by means of worm-and-screw gearing, which drives the wheels into which work two iron rails fixed round the outside of the furnace.

By a very ingenious arrangement the throat of the furnace is protected by a water-jacket, which, however, is filled with liquor from the feed tank, and by a suitable arrangement of pipes the concentrated liquor is driven upwards on becoming heated, and replaced by a continuous flow of cooler liquor. The liquor already concentrated to about 40° Twaddle is run into the end of the furnace farthest from the fire-box, and, coming into contact with the flames, is at once ignited, and before it has reached the lower end the organic matters are completely burnt up, with the result that the black ash which drops out in a continuous stream from the opening under the protecting jacket is ready for the lixiviator.

CHAPTER XVI.

TESTING OF CHEMICALS.—TESTING WATER FOR IMPURITIES.

Caustic and Recovered Soda.—The amount of actual soda (Na_2O) present in caustic and recovered soda is determined by means of the reaction with a solution of standard sulphuric acid. This standard or normal solution of sulphuric acid may be prepared in the following manner.

Strong sulphuric acid is diluted with water in a porcelain basin until the solution stands about 6° Twaddle. After the acid and water have been thoroughly mixed together, a sufficient quantity is withdrawn to fill a 50 *c.c.* burette to the zero mark. To ascertain if this solution is normal 1·06 grams of pure dried sodium carbonate are dissolved in boiling water in a small flask, and coloured with a few drops of litmus. The acid solution is then allowed to flow into this soda solution until the blue colour is discharged.

As the acid is being run in, the flask should from time to time be shaken with a circular motion so as to ensure that the point when the reaction is complete

may be the more quickly determined. When the solution in the flask begins to take on a slightly purple tinge the flow should be checked until it merely drops slowly, and the flask gently shaken until the appearance of a faint violet colour shows that the soda originally present is neutralised by the acid, when the cock should be shut, and the number of *c.c.* run off carefully noted.

To ensure that the discharging of the blue colour is not due to the carbonic acid present in the soda solution, the flask should be placed above a Bunsen burner and the contents boiled for a few minutes, when in all likelihood the blue colour will be restored, owing to the expulsion of carbonic acid.

More of the acid must then be added, drop by drop, until the red colour is permanent after boiling. If the solution is normal exactly 20 *c.c.* will be required to do this. Should more be necessary it is too weak, and more of the strong acid will require to be added to the contents of the basin and vigorously stirred before another quantity for testing is withdrawn.

Should less than 20 *c.c.* be sufficient to complete the reaction, more water will require to be added to bring it to the desired strength, which may not be arrived at until several testings have been made. For greater accuracy 2·12 grams may be taken, and in that case 40 *c.c.* will be required to turn the litmus red permanently after boiling.

When the solution has been brought to the exact strength it should be transferred to a large wide-

mouthed, well-stoppered bottle, which should then be labelled "Standard Sulphuric Acid 1 *c.c.* = ·031 gram Na_2O."

To carry out the actual test a small quantity—about 2 grams is a convenient amount—of an average sample of the soda to be tested is accurately weighed out and boiled with water in a flask until all that is soluble is dissolved. When testing recovered soda the sample should be reduced to powder, by passing it through a small coffee grinder, so that the portion weighed out may be as uniform as possible; and, after boiling, the contents of the flask should be poured on to a filter, and the insoluble portion well washed, the washings being run into the flask containing the filtrate.

The solution in the flask is then coloured with a few drops of litmus, and treated with the standard sulphuric acid solution, in the same way as when testing the standard acid, until it is turned permanently red after boiling. The number of *c.c.* required to accomplish this is multiplied by ·031; the result is then multiplied by 100 and divided by the weight of soda taken, in order to give the percentage of total alkali.

Example.—2 grams of recovered soda were accurately weighed out and dissolved with water, in a small glass flask, until all the soluble portion was extracted. A few drops of litmus were added to the clear solution, and then the standard acid run in, until the blue colour was discharged.

The contents of the flask were then boiled and the

blue colour restored, owing to the expulsion of the carbonic acid. The addition of a small quantity of the acid solution again discharged the blue colour, and the red tint was permanent after boiling for a few minutes. Exactly 29 *c.c.* of the acid had been run off; accordingly—

$$29 \times \cdot031 = \cdot899 \times 100 = 89\cdot9 \div 2 = 44\cdot95 \text{ per cent.}$$

By weighing out 3·1 grams of the soda, this calculation may be dispensed with, as the number of *c.c.* required indicate the percentage.

When testing caustic soda for total alkali the weighing must be conducted as expeditiously as possible, as the soda in the caustic form is highly deliquescent. A good plan is to place the piece to be weighed in a small glass beaker, the weight of which has already been accurately determined; the increase represents the weight of soda taken.

It is better to select an average sample, which will be near the weight usually taken, than to attempt to weigh out a stated quantity, as the time taken before the weight can be brought to the proper amount allows of a considerable absorption, both of moisture and carbonic acid, from the surrounding atmosphere.

As the caustic burns the fingers when handled, a small pair of brass forceps or tongs should always be used to lift the pieces when weighing.

Example.—Weight of beaker, 20·35 grams; weight of beaker and caustic, 23·80 grams; weight of caustic,

1·45 grams. 32·2 c.c. of standard acid were required to neutralise completely.

$$32\cdot2 \times \cdot031 = \frac{\cdot9982 \times 100}{1\cdot45} = 68\cdot84 \text{ per cent. } Na_2O.$$

The different grades of caustic soda met with in the market are classed according to the percentage of actual soda—Na_2O—which they contain. The lowest grade is designated by the suggestive name of "bottoms," and usually contains about 55 per cent. total alkali. It is so named, owing to the fact that it is obtained from the residue left at the bottom of the par in which the concentration has been conducted, and therefore contains a much larger proportion of impurities than the other grades. The impurities consist mainly of iron, and impart to it a brown colour.

The two forms of 60 per cent. soda are named cream and white respectively, owing to the characteristic cream colour of the former. The white caustic is obtained by prolonging the concentration until all the moisture is driven off, and then fusing with nitre, in order to remove the impurities which are the source of the creamy colour. This concentration has the effect of increasing the percentage of soda, and in order to bring it back to the desired strength it is treated with sodium chloride (common salt).

The grades which present the greatest freedom from impurities, together with the highest percentage of total alkali, are those sold as 70 and 77 per cent.; but notwithstanding the high degree of purity and conden-

sation arrived at in those grades, they usually contain a small portion of their bulk in the carbonated state.

In all probability the cost of caustic soda will, within a comparatively short space of time, be greatly reduced, and with it a corresponding reduction in the price of bleaching powder will doubtless take place. This may be confidently expected, owing to the introduction of the electrolytic manufacture of alkali.

It has been estimated from the results obtained by the recently fitted-up plant, in connection with Messrs. Holland and Richardson's electrolytic soda process, that, worked on a large scale, 1 ton of caustic soda and 2½ tons of bleach can be produced at a cost to the consumer of about £15.

Compared with £9 per ton for bleaching powder and about £10 per ton for 70 per cent. caustic, which prices are current and likely to remain so under the old methods of manufacture, the advantage to the consumer is enormous.

Alum.—Before proceeding to determine the amount of alumina contained in a sample of alum, the water of crystallisation with which it is combined must first be driven off. This is accomplished by placing a small quantity of the sample in a porcelain basin, and evaporating over the water-bath until the weight is constant.

To determine the amount of alumina, about one gram of the sample treated as described is dissolved

with hot water in a porcelain dish. A small quantity of ammonium chloride solution, together with a slight excess of ammonia, is now added, and the whole boiled gently until the alumina has been precipitated. The contents of the dish are then poured on to a filter and well washed with hot water, after which the precipitate is placed in a platinum crucible, which has been previously weighed, and heated over the blowpipe flame, in order to expel the water still retained. After cooling the crucible is again weighed; the increase represents the amount of alumina present in the sample.

The presence of iron may be detected by treating a small quantity of the alum to be tested with an excess of pure caustic potash. The alum, or sulphate of alumina, is dissolved in hot water, and when brought to boiling point the caustic potash is added, and the ebullition kept up for a few minutes. Should iron be present it will separate out as a brown flocculent precipitate.

Antichlor.—The actual amount of hyposulphite of soda present in the commercial article is determined by means of the reaction with a solution of iodine. The iodine solution is prepared by dissolving 12·7 grams of pure iodine in a small quantity of water, in which about 18 grams of potassium iodide have already been dissolved. The water must be cold, and as soon as all the iodine has gone into solution, the flask should be filled to the litre mark.

As one litre contains 1000 *c.c.*, 1 *c.c.* of a solution

prepared in this way is equal to ·0248 gram of the crystallised hyposulphite of soda, or ·0158 gram of the anhydrous salt, and therefore the solution is said to be deci-normal. In order to render the point where the reaction has been completed the more easily determined, a small quantity of starch solution is usually added to the dissolved hyposulphite before running in the iodine solution. The starch solution is prepared by dissolving about 1 gram of powdered starch in about 200 *c.c.* of water, and decanting into a small stoppered bottle.

The addition of a small quantity of glycerine to the clear solution thus obtained helps to keep it fresh for a greater length of time; but as it can be prepared without difficulty, it is better to make a fresh supply each time a test has to be made.

To carry out the actual testing, 24·8 grams of the crystallised hyposulphite are accurately weighed out, and having been dissolved in hot water, are transferred to a litre flask, which is then filled to the mark. After shaking the flask well, 100 *c.c.* are withdrawn, by means of a pipette, and run into a small flask, to the contents of which a small quantity of the starch solution is then added. From a burette already filled with the iodine solution, the dissolved hyposulphite in the flask is treated until the characteristic blue colour, resulting from the action of the iodine on the starch, is no longer discharged.

When this point is reached the iodine has de-

composed the whole of the hyposulphite, and is now present in excess. When the final point in the reaction is nearly reached, the cock of the burette should be closed so as to admit of the iodine solution entering the flask drop by drop, otherwise the actual percentage may be over-estimated. The number of *c.c.* of the iodine required to neutralise the hyposulphite indicate the percentage amount of the latter present in the sample.

When testing sodium sulphite, 6·3 grams of the anhydrous salt will require to be weighed out, after which the operation is conducted as in the case of the hyposulphite.

Bleaching Powder.—The amount of available chlorine present in bleaching powder is usually ascertained by means of a deci-normal solution of arsenious acid. The arsenious acid solution is prepared by dissolving 4·95 grams of pure sublimed arsenious acid (free from arsenic sulphide), to which about 25 grams recrystallised sodium carbonate (free from sodium sulphide, sulphite or hyposulphite) have been added, by boiling with water in a flask, and then diluting with water to 1 litre. As 1 equivalent of arsenious acid is equal to 4 equivalents of chlorine, 1 *c.c.* of this solution is, according to the following calculation, equal to ·00355 gram chlorine:—

$$\begin{array}{ccccc} As_2O_3 & : & As_2O_3 & :: & Cl_4 \\ 198 & & 4\cdot95 & & 35\cdot5 \times 4 = 142 = 3\cdot55 \text{ grams chlorine.} \end{array}$$

Each of the 1000 *c.c.* contained in the litre thus equals ·00355 gram chlorine.

In order to prevent any alteration in the solution through the action of the atmosphere, it should be poured into small stoppered bottles and kept corked until required.

To prepare the sample of bleaching powder for testing, 3·55 grams are accurately weighed out, rubbed into a thin cream with water in a porcelain mortar, and transferred to a 500 *c.c.* flask, which is then filled to the mark. The flask is then well shaken, and 50 *c.c.* of the turbid solution withdrawn, and run into a small beaker, which is then placed below the burette, already filled to the zero mark with the arsenious acid solution. The contents of the beaker are constantly stirred by means of a glass rod, while the arsenious acid is running in, and from time to time a drop from the beaker is lifted out with this rod and placed on a little of the potassium iodide and starch solution, which has been spread over a porcelain slab.

So long as any of the hypochlorite remains undecomposed by the arsenious acid, a blue stain, owing to the chlorine still present setting free the iodine in the potassium iodide to combine with the starch, will be produced; but whenever all the oxygen of the hypochlorite has been taken up by the arsenious acid, and the chlorine set free to combine with the calcium as calcium chloride, the blue stain will no longer be produced. The number of *c.c.* required to complete the reaction represent the percentage of available chlorine present in the sample, usually about 35 per cent.

The percentage of available chlorine present in the bleaching liquor, or in the drainings from the bleaching-house presses and tanks, can be determined in the same way, as each *c.c.* of the arsenious acid used equals ·00355 gram of chlorine, as before stated.

Should it be suspected that the lime mud contains chlorine, a small portion of it should be stirred up with water to a fixed specific gravity, and then tested in the same way as the bleaching powder. In this way the amount of chlorine retained by the mud from different makes can be at once determined by comparison.

Several useful Tables may be given here :—

TABLE SHOWING PERCENTAGE AMOUNT OF SODA (Na_2O) IN AQUEOUS SOLUTIONS OF VARIOUS SPECIFIC GRAVITIES AT 15° C. (TÜNNERMANN).

Sp. gr.	Per cent.	Sp. gr.	Per cent.	Sp. gr.	Per cent.	Sp. gr.	Per cent.
1·4285	30·220	1·3198	22·363	1·2392	15·110	1·1042	7·253
1·4193	29·6[illegible]	1·3143	21·894	1·2280	14·500	1·0948	6·648
1·4101	29·011	1·3125	21·758	1·2178	13·901	1·0855	6·044
1·4011	28·407	1·3053	21·154	1·2058	13·207	1·0764	5·440
1·3923	27·802	1·2982	20·550	1·1948	13·692	1·0675	4·835
1·3836	27·200	1·2912	19·945	1·1841	12·088	1·0587	4·231
1·3751	26·594	1·2843	19·341	1·1734	11·484	1·0500	3·626
1·3668	25·989	1·2775	18·730	1·1630	10·879	1·0414	3·022
1·3586	25·385	1·2708	18·132	1·1528	10·275	1·0330	2·418
1·3505	24·7[illegible]	1·2642	17·528	1·1428	9·679	1·0246	1·813
1·3426	24·176	1·2578	16·923	1·1330	9·066	1·0163	1·209
1·3349	23·572	1·2515	16·379	1·1233	8·462	1·0081	0·604
1·3273	22·967	1·2453	15·714	1·1137	7·857	1·0040	0·302

TABLE SHOWING PERCENTAGE AMOUNT OF CAUSTIC SODA IN AQUEOUS SOLUTIONS OF VARIOUS SPECIFIC GRAVITIES AT 15° C.

Specific Gravity.	Per cent. NaHO.	Specific Gravity.	Per cent. NaHO.
1·059	5	1·437	40
1·115	10	1·488	45
1·170	15	1·540	50
1·225	20	1·591	55
1·279	25	1·643	60
1·332	30	1·695	65
1·384	35	1·748	70

TABLE (BASED ON RICHTER'S) SHOWING PERCENTAGE AMOUNT OF SODA (Na_2O) IN LYES OF VARIOUS DEGREES TWADDLE.

Degrees Twaddle.	Per cent. Na_2O.	Degrees Twaddle.	Per cent. Na_2O.
4	2·07	44	20·66
8	4·02	48	22·58
12	5·89	52	24·47
16	7·69	56	26·33
20	9·43	60	28·16
24	11·10	64	29·96
28	12·81	68	31·67
32	14·73	70	32·40
36	16·73	72	33·08
40	18·71	76	34·41

TABLE SHOWING STRENGTH OF SOLUTIONS OF ALUM BY SPECIFIC GRAVITY AND DEGREES TWADDLE AT 17·5° C.

Specific Gravity.	Degrees Twaddle.	Per cent. $K_2Al_2(SO_4)_4+24H_2O$.
1·0065	1·30	1
1·0110	2·20	2
1·0166	3·30	3
1·0218	4·36	4
1·0269	5·38	5
1·0320	6·40	6

To convert degrees Twaddle to specific gravity, multiply by 5, add 1000, and divide by 1000. To convert specific gravity to degrees Twaddle, multiply by 1000, subtract 1000, and divide by 5.

Testing Water for Impurities.—To detect the presence of the salts which cause water to be hard, a little white soap, dissolved in alcohol, should be added to it. If hard, the water will at once assume a milky appearance, while, if it is soft, no change will be observed.

Magnesia may be detected by the white precipitate formed when a small quantity of carbonate of ammonia and phosphate of soda are added to a portion of the water which has been brought to the boiling point.

Soluble sulphates or free sulphuric acid are tested for by adding a small quantity of barium chloride, as, should either be present, a precipitate of barium sulphate, insoluble in nitric acid, will at once be formed.

Carbonic acid may be detected by the white precipitate of carbonate of lime formed when lime water is added to the water containing it.

To detect sulphur compounds a little mercury should be put into a bottle containing the water and allowed to stand corked up for some time. If there are any such compounds present the mercury will have taken on a dark colour, and on shaking will assume a silver-grey colour.

The presence of iron in water may be ascertained by pouring a few drops of tincture of nutgalls into a small quantity of the water contained in a glass vessel. Should iron be present a dark grey or black colour will be at once produced. The depth of the coloration depends on the amount of iron present; the greater the quantity contained the more intense is the shade.

Soluble lime impurities may be detected by the milky turbidity produced on the addition of one or two crystals of oxalic acid to the water.

APPENDIX.

EQUIVALENT WEIGHTS AND SIZES OF WRITING PAPERS.

Large Post. 16½ × 20¾	Pott. 12½ × 15		Double Pott. 15 × 25		Foolscap. 13¼ × 16½		Double Foolscap. 16½ × 26½		Foolscap and Third. 13¼ × 22		Foolscap and Half. 13¼ × 24¾		Pinched Post. 14½ × 18½		Post. 15¼ × 19		Double Post. 19 × 30½		Copy. 16¼ × 20		Medium Post. 18 × 22½	
lbs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
11	6	0	12	0	7	0	14	0	9	6	10	8	8	9	9	4	18	9	10	7	13	0
12	6	9	13	2	7	10	15	5	10	3	11	7	9	6	10	2	20	5	11	6	14	3
13	7	1	14	4	8	4	16	9	11	1	12	7	10	3	11	0	22	0	12	5	15	6
14	7	10	15	5	8	15	17	14	11	14	13	6	10	15	11	13	23	11	13	4	16	8
15	8	3	16	6	9	9	19	2	12	12	14	5	11	12	12	11	25	6	14	3	17	11
16	8	12	17	8	10	3	20	6	13	10	15	5	12	8	13	8	27	1	15	3	18	14
17	9	4	18	9	10	13	21	11	14	7	16	4	13	5	14	6	28	12	16	2	20	1
18	9	14	19	11	11	7	23	0	15	5	17	3	14	1	15	3	30	7	17	1	21	4
19	10	6	20	12	12	2	24	4	16	2	18	3	14	14	16	1	32	2	18	1	22	7
20	10	15	21	14	12	12	25	8	17	0	19	2	15	10	16	14	33	13	18	15	23	10
21	11	8	23	0	13	6	26	13	17	14	20	1	16	7	17	12	35	8	19	15	24	13
22	12	0	24	1	14	0	28	1	18	11	21	1	17	3	18	10	37	4	20	14	26	0
23	12	9	25	2	14	11	29	5	19	9	22	0	18	0	19	7	38	14	21	13	27	3
24	13	2	26	4	15	5	30	10	20	[illegible]	22	15	18	13	20	5	40	9	22	12	28	6
25	13	11	27	6	15	15	31	15	21	4	23	15	19	9	21	2	42	5	23	11	29	9
26	14	3	28	7	16	9	33	3	22	2	24	14	20	5	22	[illegible]	44	0	24	10	30	12
27	14	12	29	9	17	3	34	6	22	15	25	13	21	2	22	13	45	11	25	10	31	15
28	15	5	30	10	17	13	35	10	23	13	26	13	21	15	23	11	47	5	26	[illegible]	33	1

EQUIVALENT WEIGHTS AND SIZES OF PRINTING PAPERS.

Demy. 17½ × 22½	Crown. 16½ × 21		Medium. 18½ × 23		Royal. 20 × 25		Super Royal. 21 × 27		Double Pott. 15 × 25		Double Foolscap. 17 × 27		Double Crown. 20 × 30		Double Demy. 22½ × 35½
lbs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.	lbs.
15	12	13	15	12	18	12	21	4	14	1	17	3	22	8	30
16	13	10	16	13	20	0	22	11	15	0	18	6	24	0	32
17	14	8	17	14	21	4	24	2	15	15	19	8	25	8	34
18	15	6	18	14	22	8	25	8	16	14	20	10	27	0	36
19	16	3	19	15	23	12	26	15	17	13	21	13	28	8	38
20	17	1	21	0	25	0	28	6	18	12	22	15	30	0	40
21	17	15	22	1	26	4	29	13	19	11	24	2	31	8	42
22	18	12	23	2	27	8	31	3	20	10	25	4	33	0	44
23	19	10	24	2	28	12	32	10	21	9	26	6	34	8	46
24	20	8	25	3	30	0	34	1	22	8	27	[illegible]	36	0	48
25	21	5	26	4	31	4	35	7	23	7	28	11	37	8	50
26	22	3	27	5	32	8	36	14	24	6	29	14	39	0	52
27	23	1	28	6	33	12	38	5	25	5	31	0	40	9	54
28	23	14	29	6	35	0	39	12	26	4	32	2	42	1	56
29	24	12	30	7	36	4	41	2	27	3	33	5	43	9	58
30	25	10	31	8	37	8	42	9	28	2	34	7	45	1	60

SIZES OF BOOK AND DRAWING PAPERS.

Foolscap . . . 13¼ × 16½	Royal . . . 19 × 24	Elephant . . . 23 × 28	Colombier . . 23½ × 34½
Demy . . . 15½ × 20	Super Royal . 19¼ × 27½	Double Elephant 26½ × 40	Antiquarian . . 31 × 53
Medium . . . 17½ × 22½	Imperial . . 22 × 30½	Atlas . . . . 26½ × 34	Web . . 60 inches wide

Sizes of Cartridge Papers.

Foolscap	14 × 18¾	Super Royal	19¼ × 27
Demy	17¾ × 22½	Imperial	20 × 26
Royal	19 × 24	Elephant	23 × 28

Sizes of Lined Papers.

Pinched for 8vo	Expansion by 14½ in.
Post for 8vo	„ „ 15¼ „
Large Post for 8vo	„ „ 16½ „
Large Post for 4to	„ „ 20¾ „
Laid Large Post for 4to	„ „ 16¼ „

Various Calculations relating to Weight of Reams and Webs.

I. Given sample of paper, to find weight of web 100 yards by 60 inches wide, made to same substance. First find square inches in sample, weigh it, and from result obtained calculate weight of square inches in web.

Example.—4·22″ × 2″ = 8·44″ in sample, which weighs 25·2 grains. Square inches in web = 216,000.

$$\frac{216{,}000 \times 25{\cdot}2}{8{\cdot}44} = \frac{644{,}928}{7000} = 92{\cdot}132 \text{ lbs. avoir.}$$

II. From sample of paper given find variation in weight of ream of 20″ × 30″, 480 sheets of which ought to weigh 30 lbs.

Proceed as in the previous example, finding the final result from the square inches in ream.

Example.—177·2 square inches in sample, which weighs 135·75 grains, square inches in ream of 20″ × 30″, 480 sheets, 288,000.

$$\frac{288{,}000 \times 135{\cdot}75}{177{\cdot}2} = \frac{39{,}006{,}000}{7000} = 31{\cdot}5 \text{ lbs. per ream.}$$

III. To find weight of ream 20 × 30, 480 sheets, equivalent in substance to 54-inch web, two yards of which weigh 1 lb.

$$2 \text{ yards} \times 36'' \times 54'' = 3888 \text{ square inches} : 20'' \times 30'' \times 480 = 288{,}000 \text{ square inches in ream};$$

$$\text{therefore } \frac{288{,}000}{3888} = 74{\cdot}07 \text{ lbs. per ream of } 20'' \times 30'',\ 480 \text{ sheets}$$

IV. To find number of reams, of a given size, in web of any given number of yards, multiply the yards (in inches) by number of sheets in breadth of web; divide result by the draw; then divide number of sheets thus obtained by the number of sheets in the ream.

Example.—Given web 1900 yards 60 inches broad, to find number of reams of $15\frac{1}{2}'' \times 20''$, 480 sheets.

$$\frac{1900 \times 36 \times 3 \times 2}{31} = 13{,}238 \div 480 = 27 \text{ rms. } 11 \text{ qrs. } 7 \text{ sheets.}$$

Data for ascertaining the Number of Gallons of Caustic Liquor required to give the Number of Pounds of Na_2O necessary for a Boiling.

To find the factor, multiply the number of gallons per inch of tank by ·0518 for 60 per cent., ·0444 for 70 per cent., and ·04036 for 77 per cent. caustic.

To find the number of inches necessary to give the desired amount of soda, multiply the number of c.c. of standard acid required to neutralise 10 c.c. of the soda solution by the factor, and divide the pounds of soda required by the result.

Example.—Capacity of tank = 100 gallons per inch.

Amount of soda required = 800 lbs., 70 per cent. caustic (Na_2O).

$$100 \times {\cdot}0444 = 4{\cdot}44 = \text{factor.}$$

Number of c.c. standard acid required to neutralise 10 c.c. soda solution = 12·5.

$12{\cdot}5 \times 4{\cdot}44 = 55{\cdot}5 : 800 \div 55{\cdot}5 = 14{\cdot}4 =$ number of inches necessary to give 800 lbs. 70 per cent. caustic.

Table showing the Strength of Bleaching Powder Solutions, based on Lunge and Bachofen's Sp. Gr. Table.

Degrees Twaddle at 15° C.	Available Chlorine in grams per litre.	Degrees Twaddle at 15° C.	Available Chlorine in grams per litre.
23·10	71·79	12·00	35·81
23·00	71·50	11·00	32·68
22·10	68·40	10·00	29·60
22·00	68·00	9·00	26·62
21·20	65·33	8·00	23·75
21·00	64·50	7·00	20·44
20·00	61·50	6·00	17·35
19·00	58·40	5·00	14·47
18·00	55·18	4·00	11·41
17·00	52·27	3·00	8·48
16·00	49·96	2·00	5·58
15·00	45·70	1·00	2·71
14·00	42·31	0·50	1·40
13·00	39·10	0·00	trace

Composition of solution upon which the above table was originally founded:—

Available chlorine . . .	72·17 grams per litre.	
Chlorine as chloride . . .	6·74 "	"
Chlorine as chlorate . . .	0·13 "	"
Lime .	65·53 "	"

Weights and Measures of the Metric System.

WEIGHTS.

1 Milligram	=	·001 gram.
1 Centigram	=	·01 „
1 Decigram	=	·1 „
1 Gram	=	weight of a cubic centimetre of water at 4° C.
1 Decagram	=	10·000 grams.
1 Hectogram	=	100·000 „
1 Kilogram	=	1000·000 „

MEASURES OF CAPACITY.

Millilitre	=	1 cubic centimetre, or the measure of 1 gram of water
Centilitre	=	10 cubic centimetres.
Decilitre	=	100 „ „
Litre	=	1000 „ „

MEASURES OF LENGTH.

1 Millimetre	=	·001 metre.
1 Centimetre	=	·01 „
1 Decimetre	=	·1 „
1 Metre	=	the ten millionth part of a quarter of the earth's meridian.

1 gram = 15·43235 grains; 31·103496 grams = 1 oz. troy.
·453593 kilogram = 1 lb. avoir; 50·802377 kilograms = 1 cwt.
1 cubic inch = 16·386176 cubic cent.; 1 cubic foot = 28·315312 cubic decimetres; 1 gallon = 4·543458 litres.
1 inch = 2·539954 centimetres; 1 foot = 3·0479449 decimetres
1 yard = 0·9143835 metre; 1 mile = 1·6093149 kilometre.

French and English Thermometer Scales.

Centigrade. (C.)			Fahrenheit. (Fahr.)	Centigrade. (C.)			Fahrenheit. (Fahr.)
0	degrees	equal	32 degrees.	55	degrees	equal	131 degrees.
5	,,	,,	41 ,,	60	,,	,,	140 ,,
10	,,	,,	50 ,,	65	,,	,,	149 ,,
15	,,	,,	59 ,,	70	,,	,,	158 ,,
20	,,	,,	68 ,,	75	,,	,,	167 ,,
25	,,	,,	77 ,,	80	,,	,,	176 ,,
30	,,	,,	86 ,,	85	,,	,,	185 ,,
35	,,	,,	95 ,,	90	,,	,,	194 ,,
40	,,	,,	104 ,,	95	,,	,,	203 ,,
45	,,	,,	113 ,,	100	,,	,,	212 water boils.
50	,,	,,	122 ,,				

To convert degrees Fahrenheit into degrees Centigrade, subtract 32, multiply by 5, divide by 9.

To convert degrees Centigrade into degrees Fahrenheit, multiply by 9, divide by 5, and add 32.

To convert degrees Réaumur into degrees Centigrade, multiply by 5 and divide by 4.

To convert degrees Réaumur into degrees Fahrenheit, multiply by 9, divide by 4, and add 32.

To convert degrees Centigrade into degrees Réaumur, multiply by 4 and divide by 5.

To convert degrees Fahrenheit into degrees Réaumur, subtract 32, multiply by 4, and divide by 9.

Useful Data.

To find the cubical contents in gallons of any square or rectangular vessel, multiply the length, depth, and breadth in feet together, and the result by 6·2355. Should the measurements be taken in inches, the result will require to be multiplied by ·003607 in place of 6·2355.

To find the number of gallons contained in a cylindrical

vessel, first square the diameter, then multiply by 3·1416; divide result by 4 and multiply by depth; after which proceed as in the case of a square vessel—*i.e.*, multiply by 6·2355 if in feet, or by ·003607 if in inches.

To reduce	inches to metres, multiply by			·02540.
"	centimetres to inches, multiply by		.	·3937.
"	inches to centimetres	"	" .	2·540.
"	kilograms to pounds	"	" .	2·2046.
"	gallons to litres	"	" .	4·548.
"	litres to gallons	"	" .	·22.
"	pints to cubic centimetres	"	" .	567·936.
"	grams to grains	"	" .	15·432.
"	grains to grams	"	" .	·0648.
"	ounces to grams	"	" .	28·349.

To convert kilograms per square centimetre into pounds per square inch, multiply by 14·2247.

To convert pounds per square inch into kilograms per square centimetre, multiply by ·0703.

(From Bayley's "Chemist's Pocket-Book.")

1 pint equals 1·25 lbs., or 8750·0 grains of water.

1 gallon of distilled water equals 10 lbs., and measures 277·274 cubic inches.

1 lb. Avoir. equals 7000 grains; 1 lb. Troy equals 5760 grains; 1 oz. Troy equals 480 grains.

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